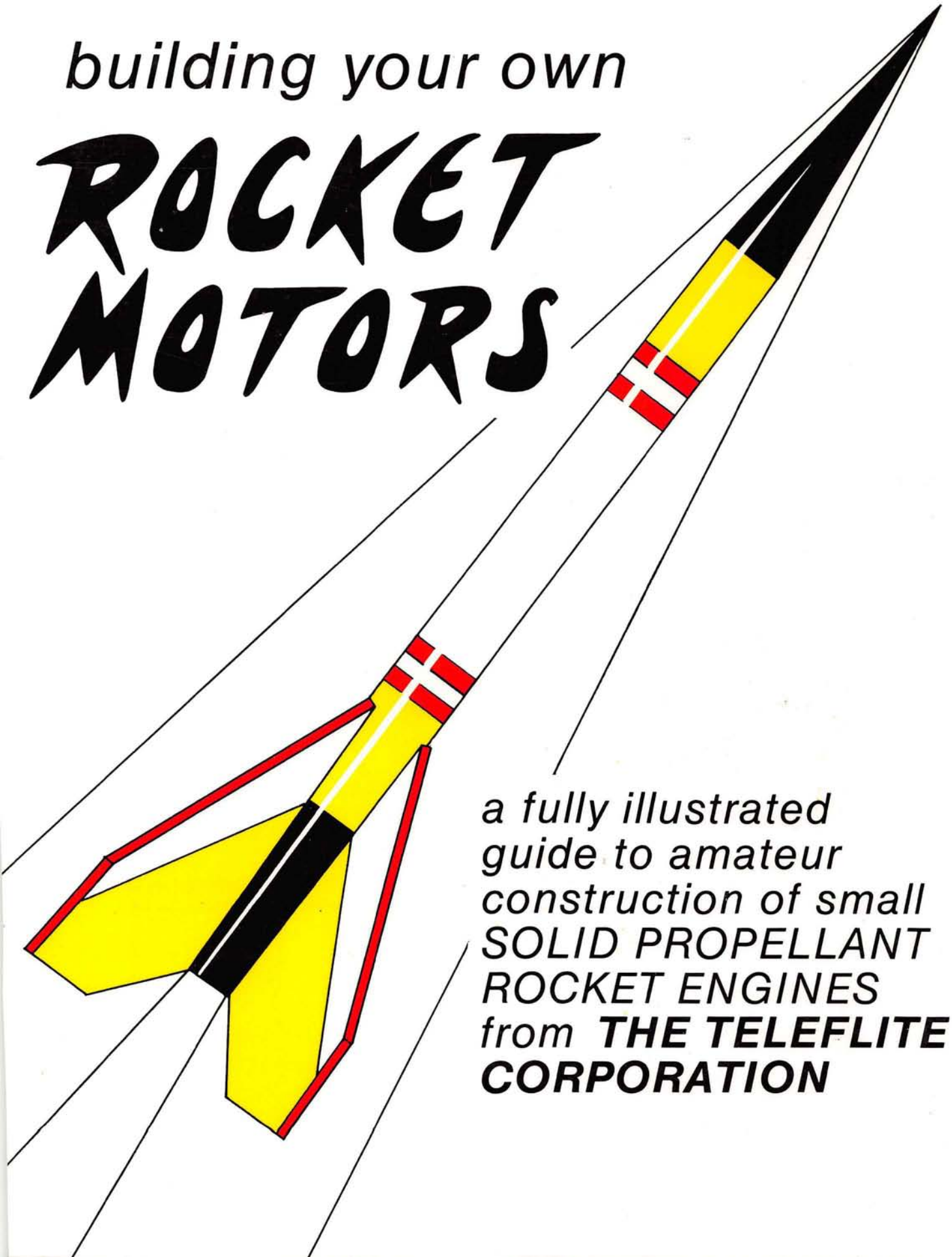
building your own

ROCKET MOTORS



a fully illustrated guide to amateur construction of small SOLID PROPELLANT ROCKET ENGINES from ***THE TELEFLITE CORPORATION***

WARNING!

The procedures described in this book and its supplements involve the making and handling of BLACK POWDER. BLACK POWDER is a POWERFUL EXPLOSIVE and must be treated with the GREATEST CARE AND RESPECT AT ALL TIMES!

The building and loading of the rocket engines described herein should NEVER be attempted by anyone under 21 years of age unless closely supervised by a PROPERLY QUALIFIED ADULT.

NO SMOKING!

KEEP BLACK POWDER and FINISHED ROCKET ENGINES AWAY FROM ALL FIRE AND FLAME at ALL TIMES! KEEP AWAY from WALL HEATERS, WATER HEATERS, STOVES, FIREPLACES, and all HOT appliances AT ALL TIMES!

WEAR GOGGLES AND A FACE SHIELD AT ALL TIMES!

DESTROY ALL UNWANTED ENGINES OR EXPLOSIVES DESCRIBED HEREIN BY SOAKING IN WATER!

NEVER attempt to convert a commercially made engine or load it with a homemade propellant, and NEVER load one of the engines described herein with anything but the properly prepared black powder described in this book.

ALWAYS USE A PROPERLY DESIGNED EXPLOSION SHIELD when loading and tamping the black powder.

ALWAYS WORK AT ARMS LENGTH when loading and tamping. In the event of an explosion, the tamping tool will be fired out of the casing like a cannon ball. It will become a high speed projectile and could do serious injury to anything or anyone in its path.

If you are at all confused about what we are saying, SHOW THIS ENTIRE BOOK TO AN EXPERT. Have him or her read it to you and EXPLAIN IT TO YOU before proceeding.

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ROCKET MOTORS

Text and Illustrations
by The Teleflite Corporation

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TABLE OF CONTENTS

	Page
INTRODUCTION	i
THE CHEMICALS	1
THE TUMBLER	2
SETTING UP THE POWDER MILL	4
MIXING THE PROPELLANT	6
HOW THE MOTORS WORK	9
CASING AND NOZZLE CONSTRUCTION	17
LOADING THE PROPELLANT	31
CURING THE MOTORS	43
MULTISTAGE IGNITION	45
PARACHUTE DEPLOYMENT	56
IN CONCLUSION	58
TROUBLE SHOOTING	59
APPENDIX A: MOISTURE CONTROL	63
APPENDIX B: SULFUR CONTENT	72
APPENDIX C: ADDITIONAL TIPS	75
THE STATIC TEST STAND	78
ENGINE PLANS (A, B, and C)	85
FORWARD BULKHEAD CONSTRUCTION	86
ENGINE PLANS (D and E)	88
ENGINE PLANS (F, G, and G100)	89

INTRODUCTION

DEAR READER:

By reading this manual and practicing its techniques you will be participating in possibly the most interesting and exciting branch of the field of rocketry. You will be building your own engines.

In the early 1960's the United States and Russia both stood on the threshold of space. Each country had launched a few small satellites, and the nation was buzzing with interest in rocketry and space travel.

Without a word of advice or a thought for safety many young people began their own experiments. Unthinkingly, they mixed up their own combinations of extremely dangerous chemicals, some of which would ignite spontaneously upon contact with one another. They rammed these combinations into metal tubes, and some of them lost eyes, limbs, and lives.

One of the hard lessons learned from those tragedies of twenty years ago is that THERE IS NO SUCH THING AS A SAFE ROCKET PROPELLANT. Any composition or substance that has locked within it the chemical energy required to lift a rocket thousands of feet into the air also contains within it the potential to blow off a hand, or an arm, or to KILL someone.

The propellant described in this manual is a classical form of BLACK POWDER. It is HIGHLY EXPLOSIVE and must be treated with CARE AND RESPECT at all times.

Our method of loading and tamping requires that you dampen the powder slightly with water. This significantly reduces its combustibility. However, even in this dampened condition it will ignite readily, and once ignited will burn furiously. You can prove this to yourself by lighting a small pile of the dampened powder from a safe distance with an electric igniter.

We wish that it were possible to wet the powder sufficiently to make it completely safe. Unfortunately, if you add enough water to accomplish this, it won't pack properly.

We think that we've done everything that we can to put safety into the techniques involved, yet keep the techniques simple. If it is within your financial means to do so, we strongly suggest that you explore the possibility of building some remote loading and tamping equipment. You would, however, have to consult an expert on this matter, as such equipment is beyond the scope of this manual. We will describe only methods that involve the use of simple hand tools.

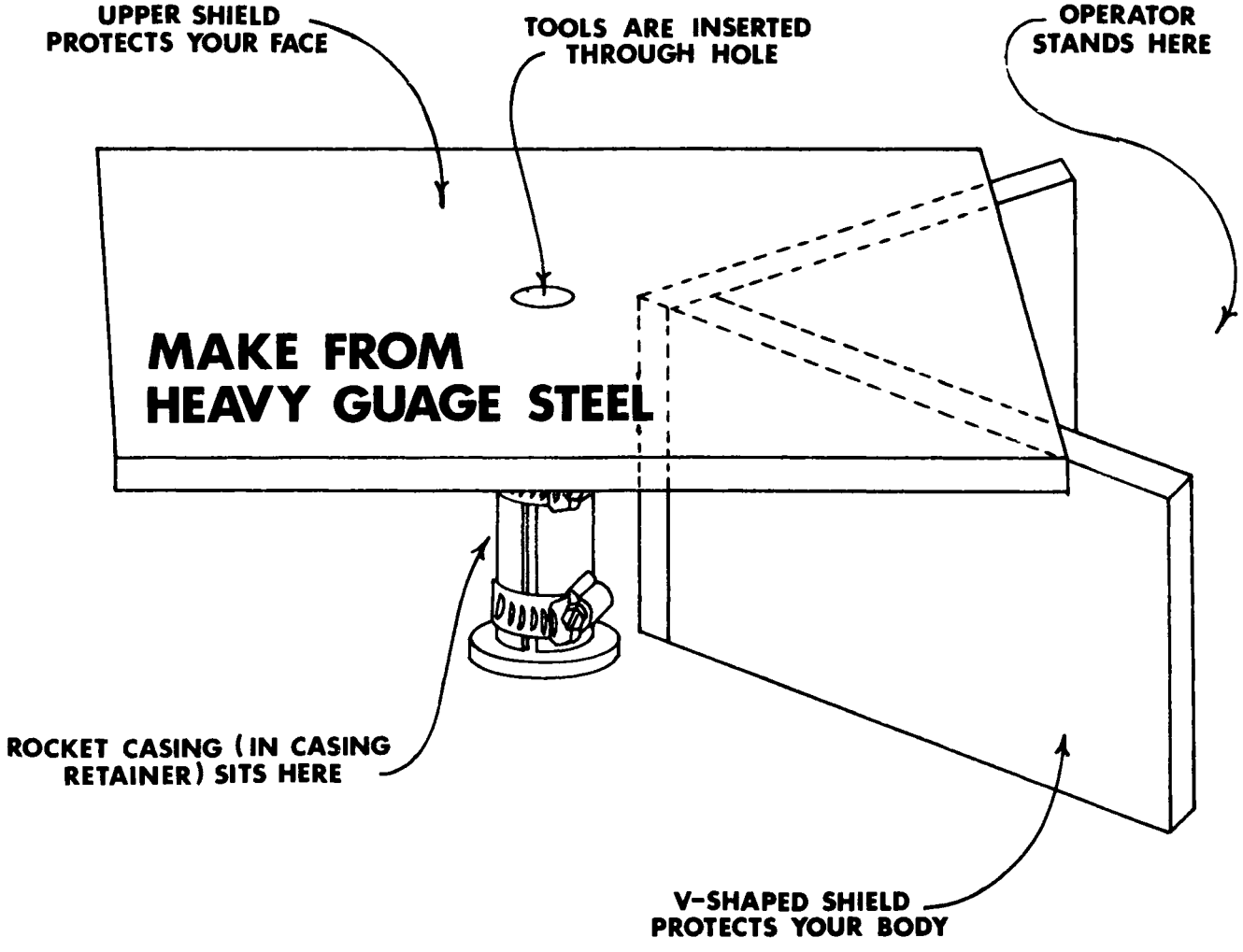
We have, however, taken the liberty of suggesting the use of a homemade explosion shield. We've sketched it below, and we feel that WHEN FOLLOWING THE TECHNIQUES DESCRIBED IN THIS MANUAL YOU MUST PROVIDE YOURSELF WITH AT LEAST THIS MUCH PROTECTION.

The shield should be made of heavy gauge steel. It should be welded or solidly bolted together. If you don't have the equipment and resources needed to construct it yourself, you should have it made for you by a qualified welder.

It is composed of a vertical, V-shaped shield which directs any explosion products AROUND you, and a horizontal, flat shield that protects your face and the upper parts of your body. The work bench surface itself provides shielding for your feet and legs.

The rocket casing is held in a simple clamping device, and the loading and tamping tools are inserted through a hole in the upper shield.

If you've built it properly, there should at no time be a line of sight between the rocket engine and any part of your body.


UPPER SHIELD PROTECTS YOUR FACE
TOOLS ARE INSERTED THROUGH HOLE
OPERATOR STANDS HERE
MAKE FROM HEAVY GUAGE STEEL
ROCKET CASING (IN CASING RETAINER) SITS HERE
V-SHAPED SHIELD PROTECTS YOUR BODY

You MUST, of course, at all times WEAR GOGGLES OR A FACE SHIELD. A long sleeved shirt and a heavy shop apron will help protect you from burns.

Remember that whatever you do, you must abide by all local, State, and Federal fire and safety regulations, and that it is advisable for you to check into these regulations before proceeding.

Black powder is not used in rocketry alone. There is a growing hobby involving the building and firing of copies of antique muzzle loading rifles and muskets. Even though the powder is hand-tamped into the barrels of these guns the hobby has an excellent safety record. Let's try to keep our safety record the same or better.

This manual is fully illustrated, and throughout the manual you will find sketches and drawings of each tool or operation. We will not show the above-described explosion shield in these drawings. It would simply get in the way of what we're trying to show you. Remember, however, that when you actually begin loading and tamping the black powder, THE EXPLOSION SHIELD SHOULD BE IN PLACE!

STOP!

Do not proceed until you have thoroughly read and understood the following section. The information discussed herein is vital to your rockets' performance. If you are at all confused about what we are saying, show this entire book to an expert. Have him or her read it and explain it to you. If you ignore this advice, you will not be able to construct a working rocket motor, and you may be at an added risk of injury to yourself or someone else.

ROCKETRY IS AN EXTREMELY EXACTING SCIENCE. The forces at play inside of an operating rocket engine are SO TREMENDOUS, yet at the same time SO DELICATELY BALANCED, that the slightest deviation from the engineering specifications will result in either poor performance or an explosion.

Commercially marketed rocket motors are manufactured by machines under very carefully controlled conditions, but the motors YOU will be building are made ENTIRELY BY HAND. Common sense should tell you that whenever you do something BY HAND there are many areas where variables can creep in and grossly affect the end results of your work.

It is, therefore, VITAL that throughout every phase of engine construction you maintain as much CONSISTENCY as possible, and it is for this reason that YOU MUST ESTABLISH SET ROUTINES for every operation. Once you've designed these routines you must stick to them FAITHFULLY. Only by doing so will you gain enough control over the building process to successfully and CONSISTENTLY produce engines of good performance quality.

The commercially marketed rocket motors use a very high grade of commercially prepared black powder, and IT IS POSSIBLE for you to make a comparable grade of powder at home. WE did it ourselves, and once we'd made this propellant, we were able to make rocket motors almost identical to the ones that you find in the hobby shops.

HOWEVER, in order to achieve this goal we had to run our powder mill for such a long period of time that even with our large equipment it was impractical to try to obtain a useable amount in less than a week.

The strength, or "specific impulse" of black powder is, to a large extent, governed by how well it is mixed. If you cut back on your grinding time, you will reduce its power. If you reduce your mill run to less than two days, or if you are using less than the best equipment, you will simply not be able to produce gunpowder of sufficient strength to make such engines work.

In the chapter that we've written on rock tumblers, we've described how to set up a small powder mill using a TOY rock tumbler; the kind that you might find at a yard sale for $5. We guessed in the beginning of our research that most of our readers would be obtaining, at least to start out with, something comparable, so of course we had to develope a method of building POWERFUL rocket motors with the lower grades of propellant produced by shorter mill runs using limited milling equipment.

Such a propellant is not capable of burning fast enough to sustain flight in an END BURNING rocket motor, but it works just fine if you form a bore hole right down the center of the rocket motor and ignite the propellant from inside this hollow core so that it burns from the center outward. In doing so, you cause ALL of the propellant to be consumed in a MUCH SHORTER span of time, and the result is an EXTREMELY POWERFUL engine with a VERY SHORT thrust duration.

Motors of this type are called CORE BURNERS, and they are ideally suited to the hand-construction techniques available to the amateur using limited equipment and producing gunpowder of limited power.

They have an additional advantage in that the depth of the core hole can be adjusted to accomodate a propellant of any given strength. This feature makes it possible for a rocket enthusiast to set up a powder milling ROUTINE and then adjust the core design of his engines to accomodate a propellant of exactly the power or "specific impulse" that his particular equipment is producing.

The PROPELLANT CORE is produced by packing dampened gunpowder around a tool called a CORING PINTLE. This tool is discussed at length in the chapter on loading and tamping. When the pintle is removed from the finished motor it leaves behind a hollow core of specific dimensions.

It WOULD be possible to adjust the design of an engine by altering the diameter of the nozzle. HOWEVER, the tools required to make a nozzle of specific dimensions require quite a bit of effort and time to make. The coring pintle, on the other hand, is a simple tapered length of round brass barstock, and in all but the largest rocket engines a new coring pintle can be made to order in less than ten minutes.

Basically it boils down to this: although it is POSSIBLE to make homemade, end-burning rocket engines, it is impractical for anyone with less than the largest milling equipment. The solution to the problem is to build CORE BURNERS, but in order to do this, you must reduce the specific impulse of your gunpowder to a SPECIFIED AND REPRODUCEABLE LEVEL. You must engineer the construction of your engine to use gunpowder of THAT SPECIFIED STRENGTH, and the easiest way to accomplish THAT is to adjust the depth of the propellant core.

If you DO decide to experiment with end-burning motors, you'll have to make the most powerful propellant that you can. It will require a lot of patience, because it may take a WEEK to obtain enough for half a dozen engines, and the cost per engine will go way up, because of the added electricity used in the extended milling process.

You will also have to develope a SLOWER BURNING gunpowder, because this fast burning material CAN'T BE USED FOR A PARACHUTE DELAY CHARGE. You'll have to pack the slower burning delay powder in on top of your fast burning propellant, and this added step will complicate the construction of your engines.

If you decide, instead, to produce CORE BURNING engines, you must strive to develope a CONSISTENT powder making ROUTINE. Try to come up with a milling schedule that will produce a practical amount of rocket propellant of the correct power, or "specific impulse" in a reasonably short length of time. If your gunpowder turns out TOO STRONG, shorten the milling time. If it turns out TOO WEAK, either lengthen the milling time, or reduce the size of the batch.

Once you find a source of chemicals, always buy them from THAT SAME source. Charcoal is made by burning wood in a controlled atmosphere. Different companies use different kinds of wood and adjust their equipment in different ways, so once you've settled on a particular "brand" of charcoal, STICK WITH THAT BRAND.

Always use THE SAME rock tumbler. Always load it with THE SAME number, size and weight of BRASS tumbling pellets. Always make THE SAME size batch, and always mill that batch for THE SAME length of time. If you follow these guidelines and establish CONSISTENT ROUTINES for every operation, you will, even with limited milling equipment, be able to produce rocket motors whose quality and power rival the finest that industry can make.

Within the text of this book we will discuss the general techniques involved in the making of the propellant, the making of the tools, the construction of the nozzles and casings, and the loading and tamping of the finished gunpowder.

Beyond the covers of this book we can provide you with what we call SUPPLEMENTS. These publications will provide you with specific plans for rocket engines made to EXACT dimensions. You MUST, however, adjust the power of YOUR gunpowder to fit OUR engine designs. We'll tell you the ROUTINE by which we made OUR gunpowder, and you'll have to adjust YOUR ROUTINE with YOUR EQUIPMENT, until your powder closely matches ours in strength.

If you find that your equipment will not produce a good enough match, you can TUNE the engine designs to YOUR PROPELLANT by either lengthening or shortening their coring pintles, and thereby deepening or shortening their propellant cores.

These engine designs are REAL CROWD PLEASERS. They are the result of many hours of experimentation. THEORETICALLY there would be an ideal nozzle diameter and core length for each size of engine casing. We have, however, suggested two or three combinations in each diameter category. These optional designs will give you some added flexibility on the flying field and on the drawing boards when you are designing models in which to use them.

WHAT YOU ARE ABOUT TO READ IS A SUGGESTED METHOD WHICH YOU CAN USE TO ESTABLISH YOUR MILLING AND CORING PARAMETERS. It's the way WE did it, and it's a simple, common sense, trial and error approach that requires no special equipment. If you keep accurate records of your experiments, it should yield good results in a surprisingly short period of time.

YOUR PROPELLANT SHOULD ALWAYS BE MADE FROM INGREDIENTS THAT HAVE BEEN WEIGHED AS ACCURATELY AS POSSIBLE. Small variations in sulfur content can radically alter the power of your gunpowder. If you designed an engine to use a propellant based upon a reduced sulfur content, and during weighing erred in the direction of MORE sulfur, you would risk an EXPLOSION on the launch pad!

Schools, universities, laboratories, and numerous institutions have ACCURATE WEIGHING EQUIPMENT. Make arrangements with one of

these organizations, or someone who owns the proper equipment, to borrow it or use it for a few hours. Using THEIR equipment and a box full of zip-lock plastic bags you can weigh out several dozen DOSES of each ingredient, all to be stored and used at a later date.

Start by building one of our engine designs EXACTLY as described in the SUPPLEMENTS. Read and understand the ROUTINE we used in making our propellant. Use the same recipe we used and the same percentage sulfur content, but scale the overall size of the batch up or down to match the size of your equipment.

Make one batch of propellant by milling the ingredients for the same length of time that we did, and build two or three copies of the chosen rocket motor design using this propellant.

Dry these motors thoroughly and test fire them. If they explode on the test stand, shorten the mill run or further reduce the sulfur content.

If they fire without mishap, make, dry and test fire two or three new engines with a NEW batch of propellant milled a couple of hours LONGER than the first batch. Keep increasing the milling time until the motors begin exploding on the test stand. Then back off to a safe mill run and from then on STICK TO THAT ROUTINE.

If you wish to experiment with a more powerful version of this propellant, either lengthen the milling time or increase the sulfur content, or both. Your propellant cores will have to be correspondingly shortened.

If you wish to develope a slow-burning powder, reduce the sulfur content. Be warned, however, that cardboard engine casings are limited in their ability to withstand a long burn, and should your burn time become excessively long, the propellant will actually burn through the engine wall.

NEVER FIRE A ROCKET ABOVE GROUND until its design has been thoroughly tested. An exploding model rocket engine scatters burning chunks of paper and propellant over a wide area, and COULD EASILY START A FIRE OR INJURE SOMEONE, YOURSELF INCLUDED! An exploding model rocket engine DOES NOT make a good firecracker. It only makes A MESS. If you want to watch things explode, wait until the Fourth of July. Then attend a good fireworks display. It's much more entertaining.

Since at least a few of your early designs WILL EXPLODE you MUST set up a workable and SAFE underground test facility. This is simple and inexpensive to do, and we've sketched one on the following page.

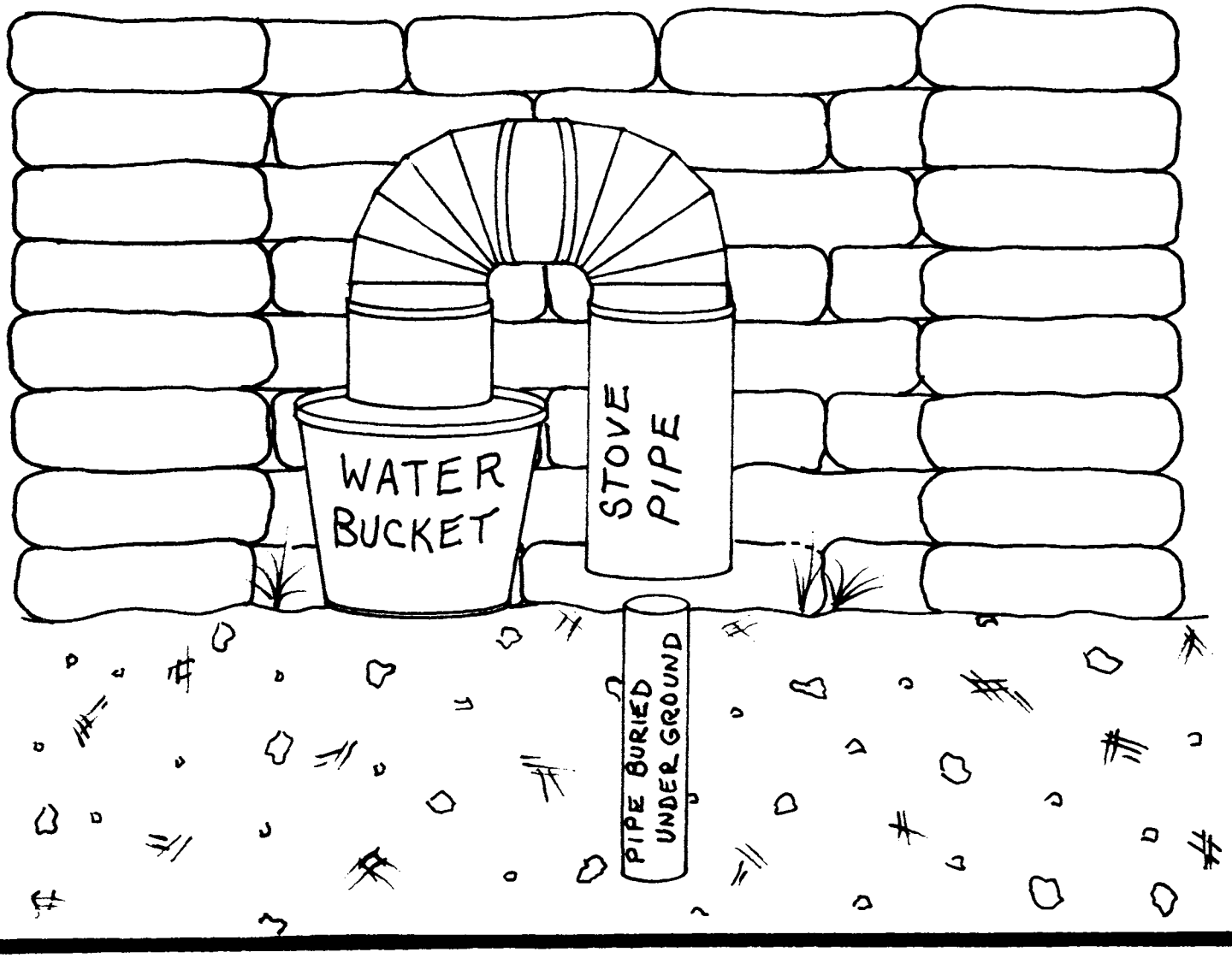
Purchase a two foot length of 4 inch diameter plastic water pipe and sink it to its full length vertically in the ground. FIRMLY ANCHOR over this pipe a U-shaped assembly of stove pipe. Place

one leg of the U over the pipe in the ground, and place the other leg over a large bucket of water. Surround the entire facility with a sandbag wall.

Place the engine to be tested POINTING DOWN in the pipe in the ground. The rocket exhaust fires UP. If the engine explodes, the U-shaped stove pipe assembly channels ALL the explosion products into the water bucket where they are immediately quenched. The sandbags provide an additional margin of safety.

When you're not using the facility to test engines, you should use it to contain your powder mill. Place your milling equipment INSIDE the sandbagged fortress. Lay a sheet of very thin plywood on top, and cover the plywood roof with a child's plastic wading pool filled with water. BE SURE to provide a couple of BAFFLED OPENINGS in the sandbag wall to allow air circulation into and out of the containment. If you ever have an explosion large enough to burst through the wading pool roof, the fire below will be instantly quenched with 50 gallons of water.

Use PATIENCE, CARE, and COMMON SENSE in everything you do. With a little practice and experimentation you'll be successful. If you try to hurry or shorten your established routines, you'll be bound for disappointment.



THE CHEMICALS

If you live in a major city you may be able to find a chemical supplier who'll repackage and sell you small amounts of the required ingredients at greatly inflated prices. However, you can purchase everything you need much less expensively from a local NURSERY or AGRICULTURAL supply. Look in the Yellow Pages under FERTILIZERS.

POTASSIUM NITRATE is the main ingredient of black powder. It is also known as SALTPETRE, and you can purchase it two ways locally.

You can buy small amounts of a refined grade from your local pharmacist. It comes in 4 oz. bottles, and each bottle sells for a little more than a dollar. If he doesn't have it on hand he'll probably be happy to order it for you.

If you've decided to obtain a large quantity of it you can buy a 50-lb. bag from just about any place that handles large quantities of fertilizer. A 50-lb. bag will cost you about $20. We've checked around quite a bit, but at this time there doesn't seem to be a way of buying an intermediate amount at a reasonable price.

The stuff the farmers use comes in a form known as "prilled grade". What you'll get is a big bag of little white beads, or "pearls". These beads have to be crushed up, but that's easy to do, and we'll tell you how to do it later.

CHARCOAL is the second most abundant ingredient in black powder. It comes packaged as "horticultural charcoal". It is manufactured in little quarter-inch sized chunks, comes in two pound bags, and sells for about a dollar a pound.

SULFUR, the third ingredient, is packaged as "dusting sulfur". It comes in 4-lb. bags and costs about 50¢ per pound. If you buy either the sulfur or the charcoal in larger quantities like the potassium nitrate the price drops considerably.

Both the potassium nitrate and the sulfur are better than 99% pure, more than refined enough to make an excellent rocket propellant. PLEASE NOTE THE FOLLOWING. Do NOT attempt to grind up charcoal briquettes (the kind you use in your Bar-B-Que). They are not pure charcoal. They are loaded with additives and binders that will interfere with your rockets' performance.

All three of the above ingredients are completely non-explosive when stored separately. When intimately mixed in the proper proportions they constitute a powerful propellant capable of lifting your rockets thousands of feet into the sky.

THE TUMBLER

BLACK POWDER is a mechanical mixture of POTASSIUM NITRATE, CHARCOAL, and SULFUR. It CAN be mixed by hand, but the process is EXCRUCIATINGLY SLOW and DANGEROUS, and it would be IMPOSSIBLE to ever obtain a product consistent enough in quality to be used in rocket engines. To make gunpowder of CONSISTENTLY REPRODUCIBLE STRENGTH and POWER you MUST use a MACHINE, and the machine of choice is a ROCK TUMBLER.

Rock tumblers are used by lapidary workers to smooth and polish small semiprecious gemstones, but for our purposes they make EXCELLENT powder mills. When properly loaded with BRASS tumbling pellets and the proper amounts of each of the three required ingredients, a rock tumbler will, within 24 hours, produce a load of quite acceptable homemade rocket propellant.

Rock tumblers are commonly sold in four sizes for hobby use. They are designated in terms of their "poundage". This figure theoretically represents the maximum weight of a load of gems that they are capable of handling. However, this method of size measurement is deceptive, and we've taken to referring to them also in terms of their volume capacities. We've prepared a small chart below which shows the advertised "poundage" as it relates to barrel volume and suggested daily powder production.

TUMBLER SIZE	BARREL VOLUME	MAXIMUM DAILY POWDER PRODUCTION
1 1/2 LBS.	1 PINT	2 TO 4 OZ.
3 LBS.	1 QUART	1/2 LB.
6 LBS.	1/2 GALLON	1 LB.
12 LBS.	1 GALLON	2 LBS.

The smallest tumblers are available in two types. The first is the toy version. These are usually sold in the toy departments of large department stores. They are inexpensively made and sell for prices ranging from $15 to $25. They generally come in a kit with various grades of grinding and polishing compounds, all of which are totally useless for our purposes. They don't do a very good job, and their little plastic containers tend to leak liquid when the seals deteriorate.

They have, however, one advantage. You can usually pick them up at yard sales or swap meets for less than $5. Parents buy them for their kids, and when the kids lose interest they get relegated to the closet. If you can lay your hands on one of these, make yourself a new gasket for the cap from an old automobile inner tube. Next take an old motorcycle inner tube, and cut out three wide, stout rubber bands. The little plastic tumbling con-

containers are made of smooth plastic. When used for tumbling rocks, which are relatively light, they work fine, but when you load them with the heavy BRASS pellets necessary to grind your gunpowder they will usually just sit there motionless while their little rollers spin beneath them.

What you need to do is to stretch around the circumference of the barrel the three stout rubber bands that you just cut from the motorcycle inner tube. This will give the barrel a better gripping surface, and you'll be on your way to a small load of rocket propellant.

The second version of this size of tumbler is a truly well made tool, and you can purchase one at a lapidary shop for around $40. However, we feel that we must advise you of the following.

You can buy a 3-lb. professional quality tumbler for just about the same price you'd pay for a one-and-a-half pounder. It doesn't seem to make sense, but that's how it is.

We now use a large 12-lb tumbler manufactured by a company in Washington. It's a beautifully made machine. This company makes a 3-lb. version of this machine that sells for LESS than $40.

As shown in the chart on the preceeding page, a 3-lb., or 1 quart tumbler, can produce 1/2-lb. of propellant in a 24 hour period. This may not sound like much until you consider the following points. It takes only about 10 minutes each day to empty and refill your powder mill. That means that if you did this each day for a week you'd end up with THREE AND A HALF POUNDS of rocket propellant, or enough to build more than FIFTY "D-18" engines!

These tumblers are very inexpensive to operate. Our twelve pounder has a motor that pulls 1.4 amps. At 115 volts it is rated at 160 watts. It uses 3.8 kilowatts of electricity in a 24 hour period, and at about 9¢/kilowatt hour this works out to 34¢ added to the electric bill. The tumbler produces 2-lbs of powder in that time, so the energy cost works out to a little over 15¢ per pound. Add that to the 50¢ per pound average cost of the ingredients, and you're making black powder for 65¢/lb. In the gun shops it currently sells for $7.00 per pound.

All rock tumblers have removeable lids, and it is CRITICALLY IMPORTANT that these lids DO NOT LEAK! If you've purchased a good quality machine and followed the instructions, you'll probably never have a problem. IF, however, you're using the little TOY version with a SCREW-ON CAP, you must take an EXTRA PRECAUTION to assure a good seal. After you've loaded the container and tightened down the lid, SECURE it with several tight wraps of VINYL, PLASTIC ELECTRICAL TAPE. You can find this tape in ANY hardware store. Most supermarkets carry it too. Clean the container and the lid thoroughly before use. This will help the tape stick better during tumbler operation.

When you go out shopping for your equipment, you'll probably discover two kinds of rock tumblers. One type has a ruggedly constructed metal tumbling barrel with a rubber liner. AVOID PURCHASING THIS TYPE OF TUMBLER if possible. They work fine, but they're very noisy, and in the event of an explosion the metal barrel would turn to DEADLY SHRAPNEL!

BUY THE OTHER KIND if you can find one. The barrels of this second type are made of SOLID PLASTIC or RUBBER. They would probably do much less damage in the event of an accident, AND they run MUCH more quietly.

DON'T BUY THE FIRST ROCK TUMBER THAT SOMEONE TRIES TO SELL YOU! Rock tumblers vary TREMENDOUSLY in price. You can buy a 3 pounder for $150 that has BALL BEARINGS and an EXTRA HEAVY DUTY MOTOR, but you really don't need such a machine.

Our TWELVE POUND machine cost $100. It has a solid rubber barrel, a more than adequate motor, and PLASTIC bearings for the rollers. When they wear out you just replace them. A new set of four costs $1.00 plus tax. BOTH our machines have plastic bearings, and we haven't had to replace them yet.

PLEASE NOTE: ALL rock tumblers use a type of electric motor that generates A LOT OF HEAT. Therefore, you must NEVER run your machine in a confined area unless you have provided good air circulation to allow the heat to escape.

SETTING UP THE POWDER MILL

CAUTION! You must always use BRASS or BRONZE tumbling pellets! Steel, or any ferrous metal pellets will cause sparks in the mill, and YOU WILL HAVE AN EXPLOSION! Neither is it advisable to use rocks, or glass marbles of an unknown composition. Many rocks and man made glasses contain mineral components that cause them to SPARK like flint when struck together. If this were to happen, you would most certainly have an explosion.

The BRASS or BRONZE tumbling pellets required are, to our knowledge, not manufactured anywhere by anyone. You'll have to make them yourself. We made ours from standard round BRASS bar stock, and we purchased it at a local industrial metals supplier. Once again, go to the Yellow Pages, and look up METALS.

If you're lucky enough to own one of those little metal cutting band saws, you can make the pellets yourself. If you're VERY am-

bitious with a hand hacksaw, you can make them yourself. Otherwise, the place where you can buy the brass will usually cut the pellets for you for an additional fee. This fee usually works out to a little more than half again what you paid for the metal.

Brass prices fluctuate like everything else, but at the time of the publication of this manual we paid about $5 per foot for the 3/4" diameter round. Half inch diameter round cost us $2.25 per foot.

This works out to a uniform price of $3.33 per pound for either size. We've prepared another chart below to show you the approximate weight and cost of the pellets needed to properly load each of the four sizes of tumblers mentioned in the preceeding text. If you have an odd sized tumbler, you can interpolate the figures. The prices assume that you cut the pellets yourself. If you have it done for you, then add at least 50% to the prices shown in the table.

TUMBLER SIZE	WEIGHT OF PELLETS	DIAMETER OF PELLETS	APPROX. TOT. COST	DAILY POWDER PRODUCTION
1 PINT	1 LB.	1/2 INCH	$3.33	2 TO 4 OZ.
1 QUART	2 LBS.	1/2 INCH	$6.66	1/2 LB.
1/2 GAL.	4 LBS.	3/4 INCH	$13.32	1 LB.
1 GALLON	8 LBS.	3/4 INCH	$26.64	2 LBS.

You'll notice that the one pint and one quart tumblers utilize 1/2" diameter pellets. The half gallon and gallon size tumblers each use the 3/4" diameter pellets. Each pellet, regardless of its size, should be cut so that its diameter is equal to its length. That is, the 1/2" diameter pellets are each cut 1/2" long, and the 3/4" diameter pellets are each cut 3/4" long.

When you buy the brass bar stock you must realize that when you cut it up you will have some waste equal to the total thickness of all the cuts that you make. Try to figure this into the bargain, because it will take a little more than a pound of brass to make a pound of pellets.

After you've cut the pellets you have to deburr them. We did ours on a belt sander, but a hand file will work fine. After they're deburred, wash them thoroughly in strong detergent and hot water, and dry them. They must be completely clean and free of dirt and oil before they can be used.

Once you've got them in this condition you can load them into the tumbler. You're ready to start making powder.

MIXING THE PROPELLANT

NOTICE: IF YOU HAVE NOT YET DONE SO, READ AND THOROUGHLY UNDERSTAND THE INTRODUCTION TO THIS BOOK. IT CONTAINS INFORMATION VITAL TO YOUR PERSONAL SAFETY AND THE PERFORMANCE OF YOUR ROCKETS.

IN the introduction we emphasized the importance of establishing SET ROUTINES for every operation in engine building, and NOWHERE is this more important than in the actual mixing of the rocket propellant.

We've already told you that it is possible for you to make, even with limited equipment, a grade of gunpowder comparable to that used in the commercially manufactured motors, but we've also explained why we feel that it is an impractical project for most hobbyists to attempt.

We're tentatively planning a future supplement which deals with this subject, but the motors described in THIS text are all core burners and are designed to operate on a propellant with a much lower specific impulse.

In order to make this "TONED DOWN" form of gunpowder you must LIMIT the milling time of each batch, and since CONSISTENCY is important, you must have a way of accurately timing each step in the milling operation.

You COULD do this by simply watching the clock, but if you forgot to shut down the mill at the proper time, your propellant would turn out too strong, and you'd have to discard the whole batch.

To mitigate this problem we suggest that you purchase a commercially made small appliance timer. They cost about $10, and you can find one in any hardware or discount store. You can plug your powder mill into the timer. Then you can set the timer to turn it on and off whenever you want, even when you're not there.

You can't just throw all the ingredients into your mill together and expect to end up with a good product. First, you have to crush up the potassium nitrate and the charcoal, and you do this by splitting your mill run into THREE stages.

Through trial and error we arrived at a time ratio of approximately 1 to 2 to 3. That is, for a 6 hour mill run, you would spend 1 hour crushing the charcoal, 2 hours crushing the potassium nitrate beads, and 3 hours mixing the nitrate, charcoal, and sulfur all together.

For a 12 hour mill run the times would be doubled. For an 18 hour run they would be tripled. The charcoal is so powdery when it's ground up that it's difficult to pour it in and out of the mill without losing some of it, so it's nice to plan things so that once the charcoal is crushed up it can remain in the mill throughout the rest of the operation.

WE do it in the following manner. We crush up the potassium nitrate FIRST. We then remove it from the mill and keep it in a sealed container while we grind up the charcoal. When the charcoal is done, we open the mill and load the powdered potassium nitrate BACK into the mill along with the sulfur. Then we mix ALL THREE together for the specified remaining period of time.

ALL THE INGREDIENTS MUST BE KEPT DRY. This applies especially to the potassium nitrate. If the beads are NOT dry, they will not crush into powder. They will, instead, form giant ball-shaped concretions in the mill. Once these concretions form, they are impossible to break up, and you may as well throw them away and start from scratch.

If you run into this problem, dry the beads in your kitchen oven before crushing. Put several pounds of them in a pot and bake them at 350 degrees Fahrenheit for a few hours. DON'T LOAD THEM INTO THE MILL WHILE THEY'RE STILL HOT! They'll melt the rubber!

The powder formula that we used initially is the classical mixture found in any encyclopedia. It consists of the three basic ingredients mixed in the following proportions by WEIGHT.

POTASSIUM NITRATE 75%

CHARCOAL.....15%

SULFUR.....10%

We ran the properly measured ingredients in the mill for 12 hours, and although the propellant was not powerful enough to use in an end-burning rocket motor, we were able to produce a series of core-burners that, almost literally, exploded off the launch pad.

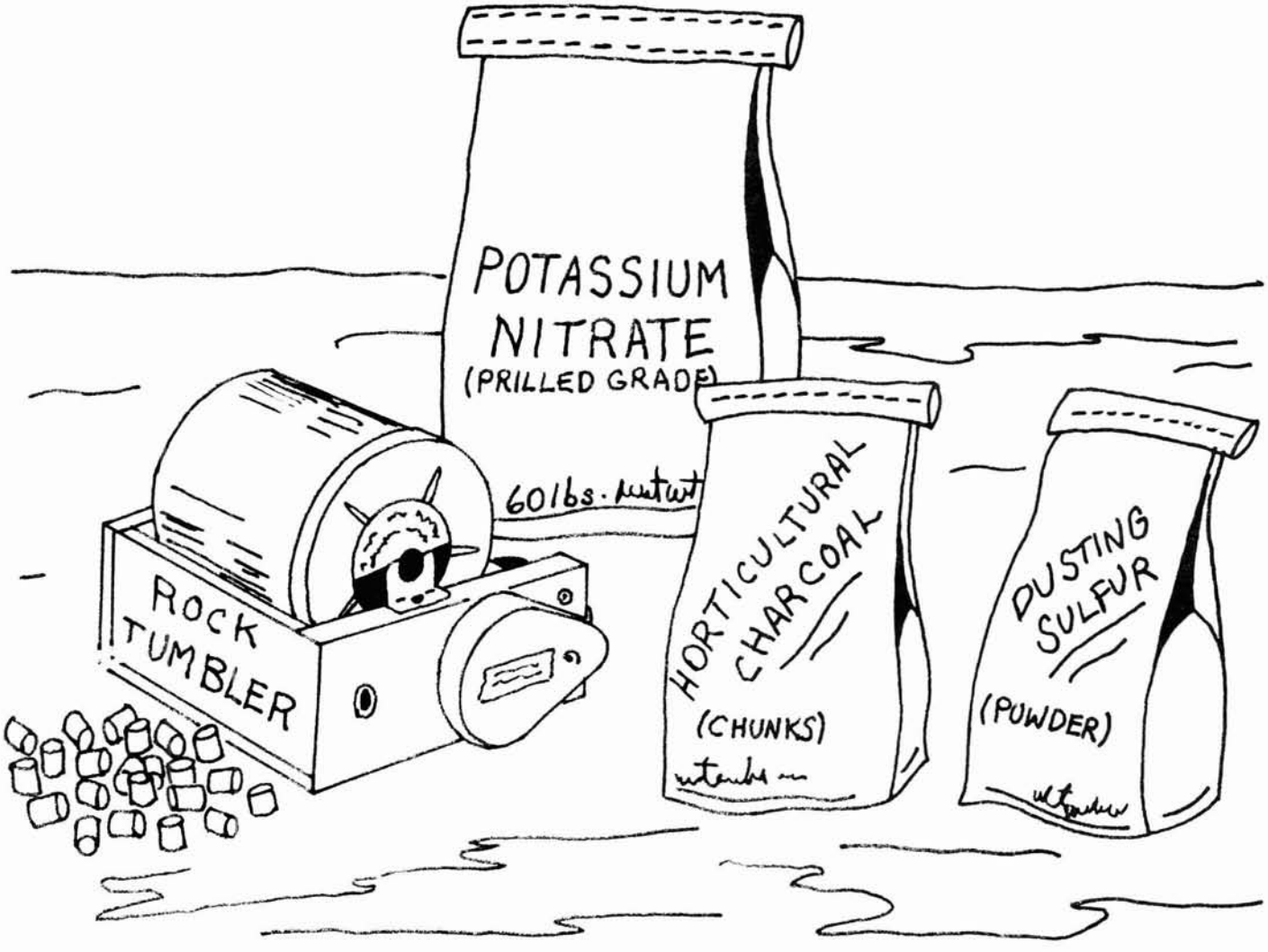
These engines had EXTREMELY short cores, and burn times, and behaved more like mortars than rockets. In order to obtain more realistic rocket performance we had to further reduce the strength of our powder. We tried to drastically shorten our mill run, but when we dropped below 8 hours we began finding unground chunks of charcoal and nitrate in the finished powder.

The power of a batch of gunpowder can ALSO be reduced by LOWERING the SULFUR content. To make absolutely sure that we were grinding everything thoroughly, we returned to the twelve hour mill run and began reducing sulfur accordingly. By playing around with the milling time AND the sulfur content we were eventually able to produce, and then duplicate a propellant ideally suited to the kind of rocket engines that we were trying to make.

As stated in the introduction, the accuracy of your weighing equipment is EXTREMELY important. If you're seriously interested in pursuing engine building as a full time hobby, we suggest that you purchase a triple beam laboratory balance. You should buy the kind that weighs up to 2500 grams and is accurate to 1/10 of a gram. A chemistry teacher or pharmacist can advise you where to purchase one. If such a scale is beyond your means, attempt to obtain permission to use one for an afternoon; long enough to weigh up several dozen doses of ingredients for future use. Store the measured chemicals in zip-lock plastic bags and write the weight of each on the bag with an indelible marking pen.

In the Supplements to this book we'll provide you with a series of exact rocket engine plans. We'll tell you exactly how we made OUR gunpowder. You will, through trial and error, have to make a propellant of equal strength. If you weigh your ingredients carefully and keep accurate records, you should achieve success quite rapidly.

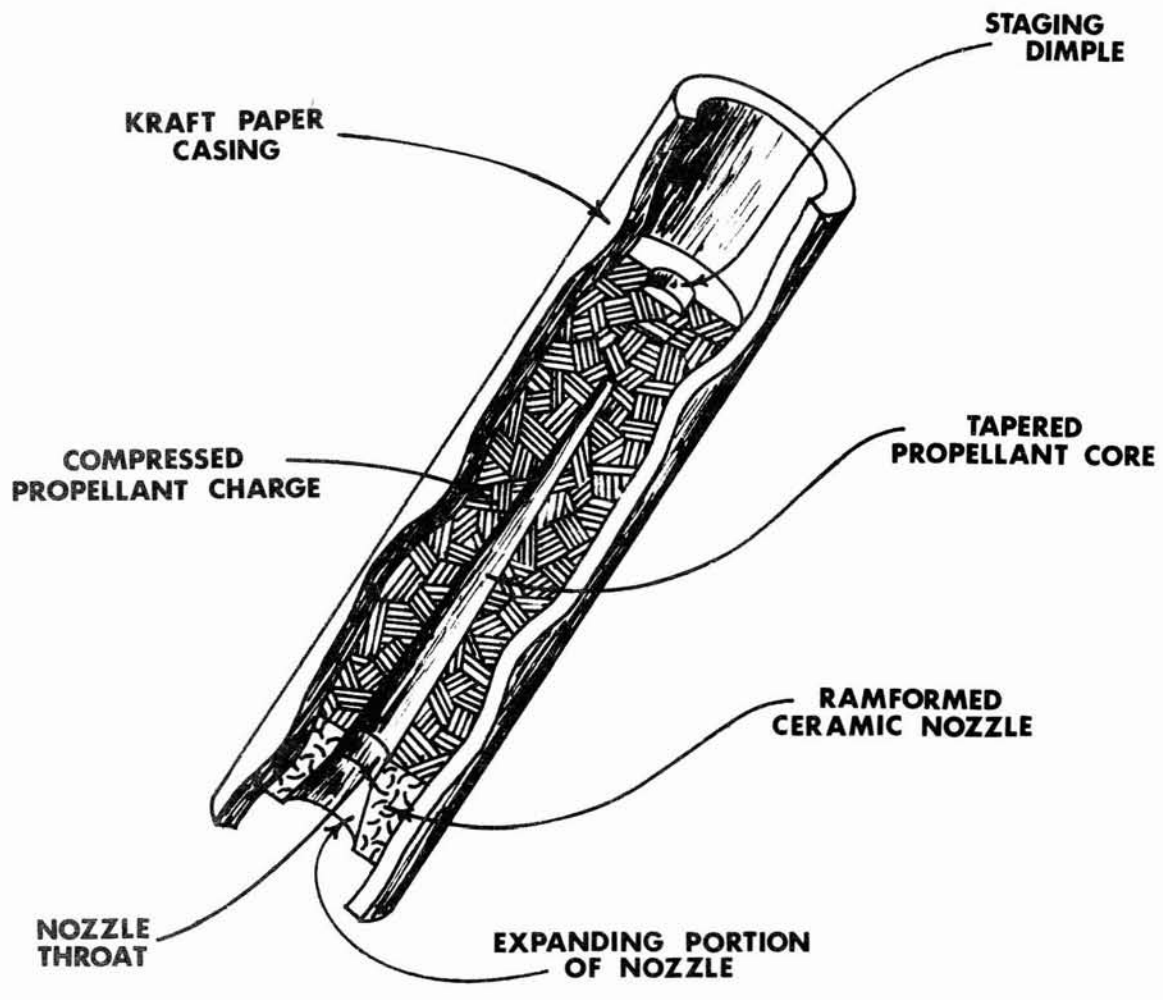
KEEP EVERYTHING CLEAN! Wash and dry your equipment periodically. If you spill any gunpowder on the floor, WET IT DOWN and WIPE IT UP IMMEDIATELY! Discard unwanted gunpowder, or ANYTHING SATURATED with gunpowder by soaking or rinsing in water. Be particularly cautious in DRY or WINDY WEATHER! BLACK POWDER CAN BE SET OFF BY STATIC ELECTRICITY, and ONE SPARK is all it takes!



HOW THE MOTORS WORK

FIGURE 1 below is a cutaway view of a typical solid propellant rocket engine as described in this manual. Look it over carefully. It is a general illustration of a BOOSTER engine. With the exception of the staging dimple in the end of the propellant charge, it's built just like its upper stage counterparts.

FIGURE 1

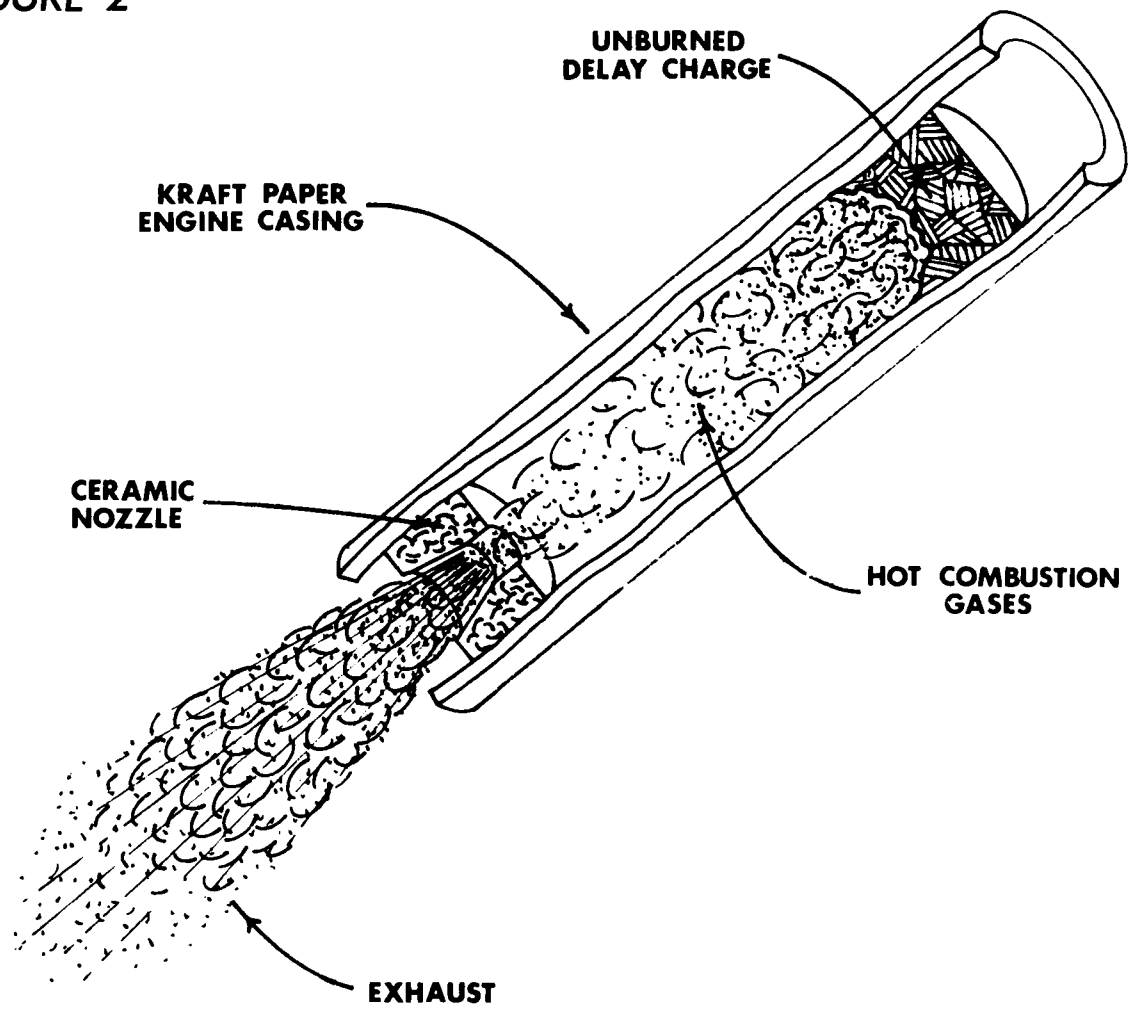


With minor exceptions, it is built just like the model rocket engines that you find in the hobby shops. That is, it consists of a convolute wound kraft paper casing, a compressed and cured propellant charge, and a ramformed ceramic nozzle.

The initial reaction of most people when they first examine one of these engines is to ask "Where's the front of the motor? What holds the powder in?" The answer is as follows.

This type of rocket motor has no "front," or "firewall" in the commonly understood sense of the word. Figure 2 below illustrates what goes on when one of these engines fires. You can see that even though the propellant is burning furiously, there is a thick, UNBURNED plug of propellant remaining in the front of the engine. This plug retains the expanding combustion gases and maintains operating pressure until it is, ITSELF, consumed during the final moments of the rocket's flight.

FIGURE 2



You may have noticed that the motor illustrated in Figure 2 is slightly different from the one illustrated in Figure 1. You are correct. Figure 1 illustrates a BOOSTER engine.

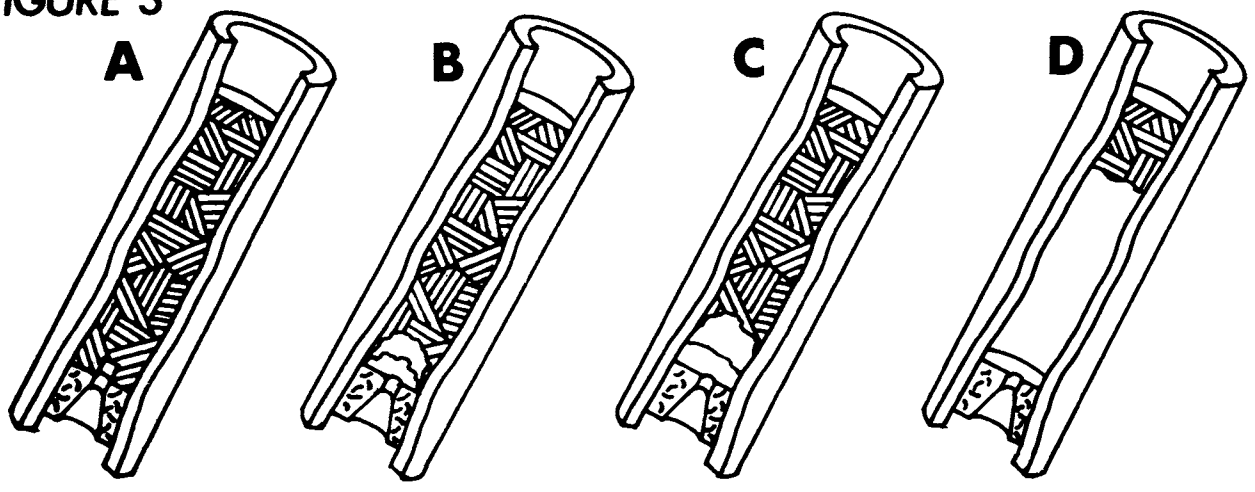
Booster engines are used to lift heavy, multistage rockets off the ground. They generate relatively tremendous amounts of thrust to accomplish this, and just beyond the peak of that thrust they ignite a second stage motor which separates and carries the rocket to even greater velocities and altitudes.

Figure 2 illustrates an UPPER STAGE engine. Upper stage engines function also as single stage engines. An upper stage engine, as described in this manual, is built just like a booster, with the exception of a delay charge which allows the rocket to coast to its maximum altitude before releasing its parachute. If you removed both illustrations from the book and held them up side by side you'd see an extra amount of powder packed into the front of the UPPER STAGE motor. This extra amount of powder IS the delay charge.

Now, before we proceed to tell you exactly how the motors are made, some further explanation is necessary. You need to have a firm understanding of what you are doing and WHY.

Most of the rocket motors that you buy in the hobby shops are loosely termed END BURNERS. That is, once the propellant is ignited it burns from one end of the motor to the other, just like a fuse or a cigarette. Once it is ignited it burns at a FIXED RATE, and the length of the burn depends upon the physical length of the motor. There is NO core, and the propellant charge is SOLID along its entire length. We've sketched such a motor below in four different stages of its burn to illustrate what we're talking about.

FIGURE 3



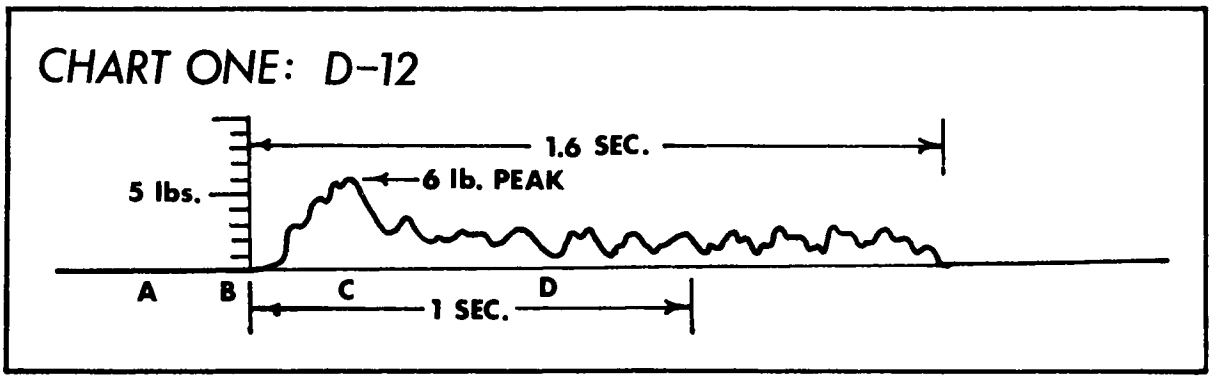
(A) shows the motor as it exists just before ignition. (B) shows the motor at the time of ignition.

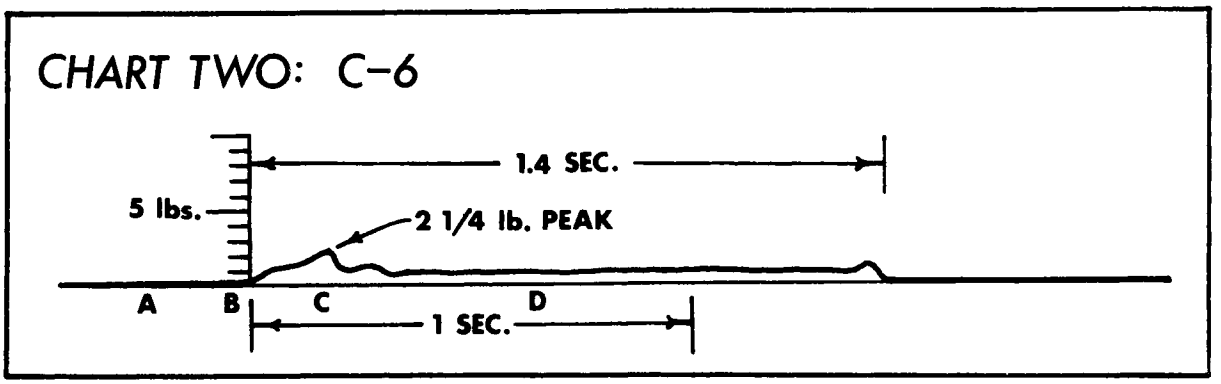
Since the propellant charge is ignited from the center of the nozzle throat and burns from that center at a uniform rate, it tends to form a dome shaped flame front. This dome shaped flame front has a greater surface area than a flat flame front, and hence, a greater amount of propellant is consumed each second than would be consumed by a flat flame front. Combustion chamber pressure and thrust are correspondingly higher, and this helps to get the rocket off the ground. (C) illustrates the motor at this point in its burn.

Commercial manufacturers actually form a little dimple in the propellant at the nozzle throat to further augment the dome effect AND they place a thin layer of fast burning, or "corned" powder at this point.

Once the perimeter of the expanding dome reaches the walls of the engine casing, everything tends to even out and the flame front tends to flatten. Chamber pressure and thrust reduce correspondingly, and both remain constant for the remainder of the burn. (D) illustrates this stage of the motor's life.

The two charts below were made on our recording dynamometer. They exactly illustrate the "Time vs. Thrust" performance of two well known commercially made end burning rocket engines. CHART ONE is the tracing of a D-12. CHART TWO is the performance tracing of a C-6. The letters, "A,B,C, and D" correspond to the four burn stages depicted in FIGURE 3.





The C-6 engine peaks at 2-1/4 lbs. of thrust about 1/5 of a second after ignition. It immediately drops to 1 lb. and remains there for the duration of the burn. Total burn time is 1.4 seconds.

The D-12 motor peaks at 6 lbs. of thrust in about 1/5 of a second. It then drops to approximately 2 lbs. where it remains for 1/4 of a second, after which it oscillates between one and two pounds for the remainder of the burn. Total burn time is 1.6 seconds.

This oscillation is clearly audible during the rocket's flight as a "stuttering" sound. The smaller commercial engines rarely do this, but the phenomenon seems to be fairly common in the D-sized motors. It doesn't really hurt anything, although it would seem that the vibration generated is not exactly easy on the structure of a lightly built model.

If you're already extensively involved in model rocketry you're aware that the company that makes these D-12 engines claims a peak thrust of 9 lbs. We consistently record a 6 lb. peak for their nine pounder.

Our testing equipment is different from theirs. We built it ourselves. It is very probable that theirs is more sophisticated and sensitive than ours, and that theirs is designed to read out engine thrust to the very last gram.

We tell you this for the following reason. If we claim that one of our engine designs peaks at 6 lbs. of thrust, then by THEIR standards, it is developing 9 lbs. of thrust. On OUR equipment their motor tests out at 6 lbs. TOO, so the two are comparable.

The difference is about 50%. We've discovered this discrepancy to be fairly consistent no matter which of their engines we were testing. That is, they always claimed about 50% more thrust than we actually recorded.

Therefore, when we claim that a motor generates 20 lbs. of thrust, you can safely assume that by the commercial industry's standards it is actually developing 30. You can also assume that when THEY claim 12 lbs. of thrust recorded on THEIR machines, the motor is actually developing only 8 lbs. according to OUR standards. This means that a motor that WE call a "D" might actually be an "E" when compared to theirs.

Remember this well, and take it into consideration when flying side by side with the commercially made models. You're liable to get some surprised looks when YOUR "D" engine leaves theirs in the dust!

Rocket thrust is a direct expression of the inertia of the gases escaping through the engine nozzle, and this inertia is a direct expression of their velocity AND their mass at any given moment.

The objective in designing a rocket motor is to maximize each factor without diminishing the other to such an extent that the NET result is reduced.

Since the power or "specific impulse" of the propellant is fixed by the laws of chemistry, maximizing the thrust of an end burning engine becomes a simple matter of experimenting with various diameters for the nozzle until the optimum performance is achieved.

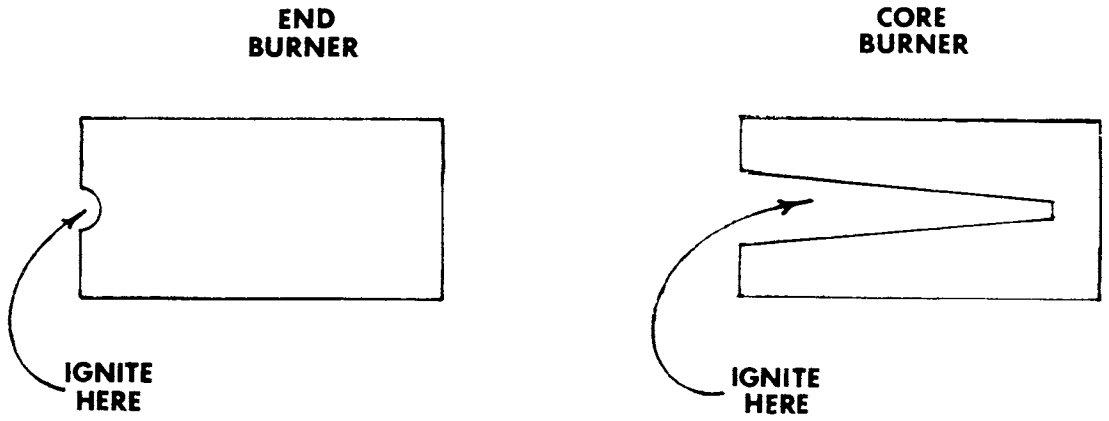
The motors that you buy in the hobby shops use the more powerful form of black powder that we've already discussed. As we've stated before, it IS possible to produce this powder by vastly lengthening your milling schedule and decreasing your batch size, but for anyone with less than the largest tumbling equipment it would be difficult to obtain a useable amount in a reasonable length of time.

We've experimented with end-burning motors using our less powerful black powder, and they DO take off and fly, but they are little more than freakish curiosities. They have extremely long burn times, very tiny nozzles, and they generate barely enough thrust to lift themselves off the ground, let alone carry a model with a recovery system.

To make this low powered black powder work, you must figure out a way to make it burn faster. The sluggish and impractical motors described above carry about an ounce of propellant and take about three seconds to burn it up. If you can figure out a way to get it all to burn in about a HALF a second, then you've accomplished your goal.

You do this by introducing a CORE into the propellant charge. A core is a hollow bore hole drilled or formed right down the center of the cylindrical propellant charge. Instead of igniting the propellant charge at one end and allowing it to burn to the other, you ignite it in the center and it burns from that center outward to the walls of the casing. We've sketched the two types of propellant charge below. The one on the left is an END BURNER. The one on the right is a CORE BURNER.

FIGURE 4



Remember that the propellant burns at a fixed rate; let's say one inch per second. The END BURNER shown in FIGURE 4 is about two inches long, so if we light it at one end it will take the flame two seconds to reach the other.

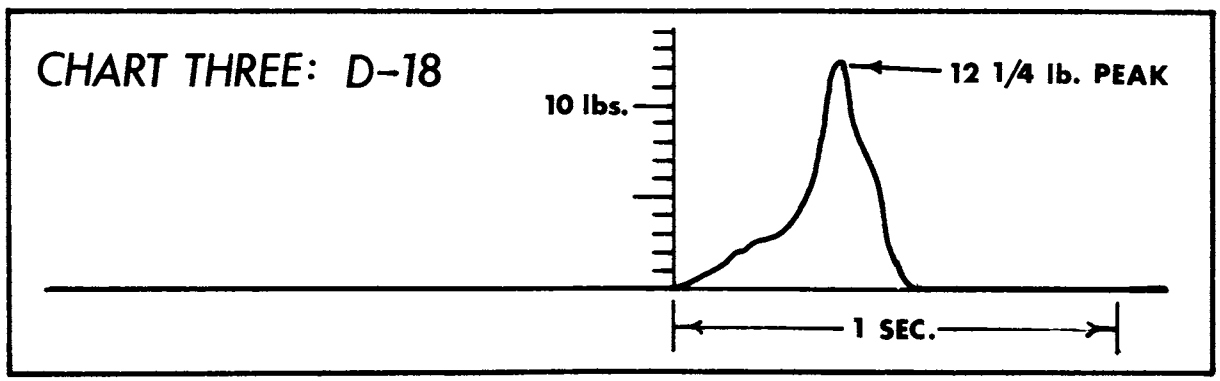
The CORE BURNER on the right is the same length and diameter as the end burner. However, we stick the igniter right into the central core, or bore hole, and therefore this propellant charge burns from the center to the outside. Since the diametrical radius of the propellant charge is only half an inch, it will take the flame only half a second to travel that distance and consume ALL the powder. We've effectively QUADRUPLED the burn rate of the rocket motor.

Of course we've had the forethought to design a much larger nozzle to handle the rapidly expanding exhaust products, and in doing so have created a VERY powerful rocket motor.

ALL the motors described in this manual are CORE BURNERS. Core burning engines have a very distinctive power curve. Since they burn from the center outward, the surface area of the flame front, and correspondingly the volume of the propellant being consumed at any given moment, increase steadily until the flame reaches the walls of the casing. At this point the propellant is entirely consumed and the thrust drops rapidly back to zero. If the engine is a booster, it will ignite a second stage motor at this point. If it is an upper stage motor, the additional powder packed in front of the core functions as a delay charge which generates a trail of tracking smoke and at the same time allows the rocket to coast to apogee before deploying its parachute.

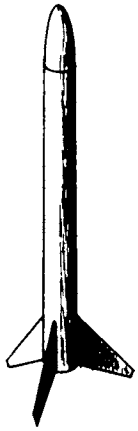
CHART THREE below illustrates the performance curve of a D-18 CORE BURNER. Once again the readings were taken on our equipment, so it's quite a bit more powerful than a commercially rated D-18. Note that the burn time is short when compared to the burn time of the commercial D-12 illustrated in CHART ONE.

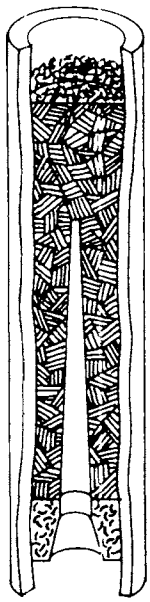
When you've thoroughly examined this chart, turn to the next page. You'll find a two page pen sketch illustrating the ENTIRE FLIGHT of a single stage core burning rocket.



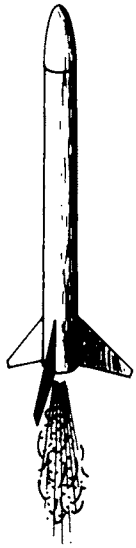
THE FLIGHT OF A SINGLE STAGE ROCKET

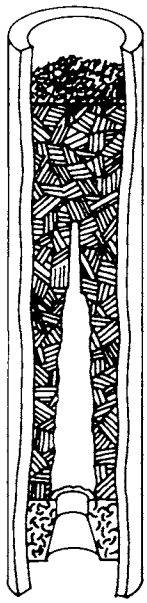
A



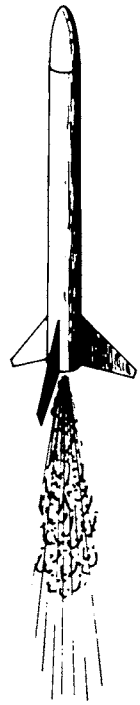


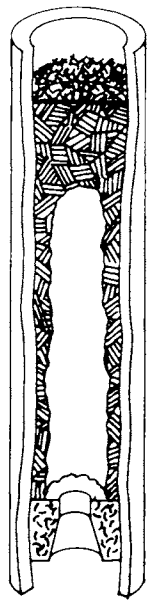
B

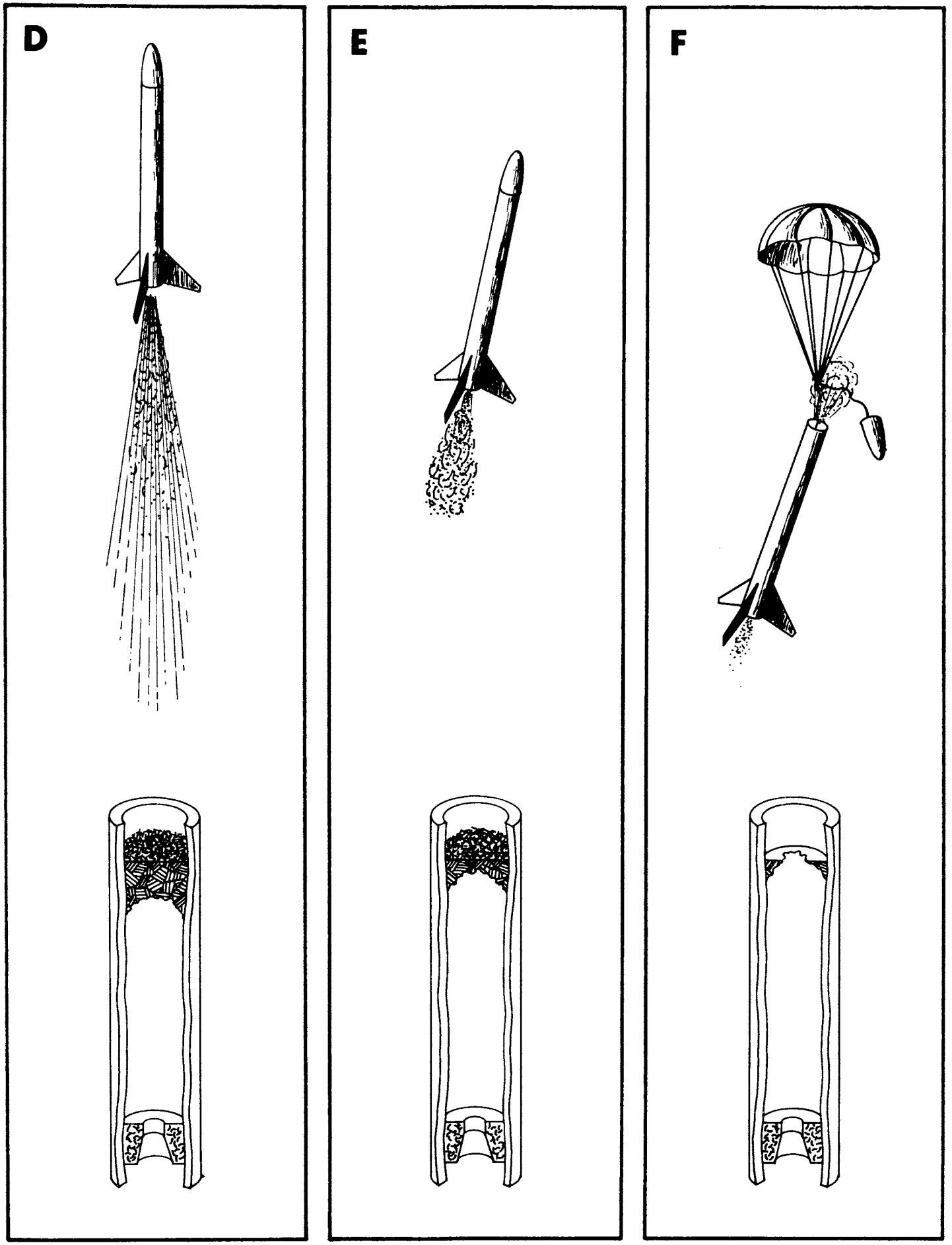




C






D
E
F

Beneath each picture is a cutaway view of the rocket's motor at that exact point in its flight. Each view shows exactly how the propellant is burning and just how much propellant is left over. The dark, cross-hatched material is the compressed and cured gunpowder. The grainy looking stuff at the front of the motor is a measured amount of LOOSE, DRY black powder. When the flame finally reaches it, it explodes in a FLASH, producing a burst of gas that ejects the rocket's parachute.

(A) shows the rocket and its motor just before lift off. Notice the long, tapered core. An electric igniter is inserted into this core and fired by a jolt of electricity from a car battery.

The result is (B). The propellant begins to burn, and the rocket lifts off the launch pad.

At (C) the propellant is being consumed at an ever increasing rate. Engine thrust is increasing rapidly, and the rocket is accelerating upward.

At (D) the velocity and thrust are both at their maximum. The advancing flame front has JUST consumed the last remnants of propellant clinging to the walls of the combustion chamber. Following this, both chamber pressure and thrust will drop rapidly. There is still some propellant remaining in the front of the engine, but since the nozzle was engineered to handle a CORE BURNING propellant charge, it will not derive any thrust from this, and the remaining powder will function strictly as a delay charge.

The rocket now enters its coasting phase. It is still climbing rapidly upward, but decelerating at every moment. (E) illustrates this point in its flight. Even though the engine has ceased to generate thrust, it still makes an impressive hissing sound and puts out a gorgeous smoke trail. An inexperienced ground observer would believe that it is still traveling under full power.

The rocket will continue to coast upward in this manner until it has lost all its velocity. If you've designed your engine properly, the apogee (high point) of the rocket's flight will exactly coincide with (F). At this point the advancing flame front burns through to the loose powder stored at the front of the engine and EXPLODES it, thus ejecting the rocket's parachute which brings the entire model gracefully back to earth.

Now that you have an understanding of how these motors work, we can go on to explain exactly how to make them. All the motors described herein are real crowd pleasers, and even the smallest is capable of carrying a properly designed model well beyond a thousand feet. Multistage configurations of the larger engines will carry your models to absolutely telescopic altitudes. When you fly these larger engines bring along a good pair of binoculars, and don't fly them on a windy day, or you'll find yourself hiking several miles to recover that third stage.

CASING AND NOZZLE CONSTRUCTION

As stated on page 10, these rocket engines feature ramformed ceramic nozzles. They are essentially identical to the ones used in the commercially made motors, and in case you thought that they were made by some special process out of some space age material, you're in for a pleasant surprise.

Go to the Yellow Pages once more and look up LANDSCAPING or CONCRETE. Anyone who handles cement blocks or brick laying supplies will also sell FIRECLAY. Fireclay is used by brick layers to make their mortar sticky, so that it will adhere to vertical surfaces. Fireclay is highly "refractory." That is, it is highly heat resistant and is capable of withstanding temperatures measured in thousands of degrees Fahrenheit. Fireclay is the major ingredient of the ceramic nozzles that you'll be making. It comes in a dry, powdered form, and you can buy a 60 lb. bag of it for less than five dollars.

The second ingredient that you'll need is not quite so common, but is still readily available if you know where to find it. It is called GROG. Anyone who dabbles in ceramics should know what GROG is. Potters add it to their clay to give it "tooth" That is, to make it rough.

If you've ever handled a coffee mug or some other piece of stoneware that seemed to have a rough, sandy texture to it, well, you know immediately that the artist added GROG to his clay to make it feel like that.

You make GROG by simply grinding or smashing up old, unwanted or broken pieces of pottery and sifting the results through sieves. You can't use regular beach or river sand as a substitute for it, because the pottery that the GROG was made from has already been baked in a kiln at a couple thousand degrees. This makes the pottery, and hence the GROG, highly refractory just like the fireclay.

Just about every little town in the nation harbors a small ceramics business. These businesses have sprouted up like mushrooms over the last ten years. They give china painting classes, and you can buy just about any ceramic material that you need through them. They don't usually have grog in stock, because they rarely have a use for it, but their suppliers carry it, and they can normally order it for you on a week's notice. In small quantities of five pounds or less you can expect to pay about a

dollar a pound, but once again, if you order a one hundred pound bag, the price will drop to about 20¢ per pound. That big bag of grog will cost you about $20, and it should last you a lifetime.

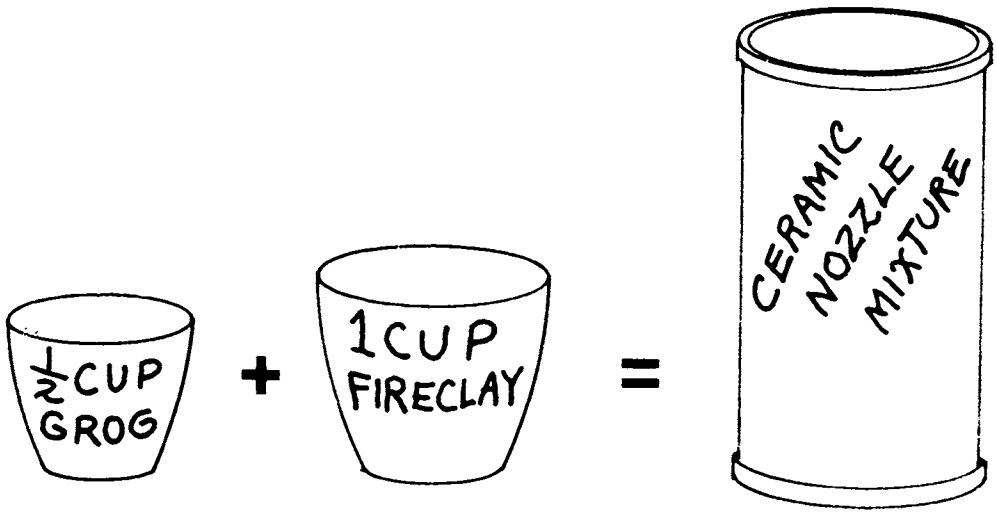
Grog is normally available in four grades as follows: coarse, medium coarse, medium fine, and fine. The MEDIUM FINE is best, but if you have trouble obtaining it, the medium coarse should work alright.

The rocket engine nozzles are made from a simple mixture of these two ingredients. You combine them DRY in the follow proportions by VOLUME.

FIRECLAY. . . . . .2 PARTS

GROG. . . . . 1 PART

When we make it up, we take a big grapefruit juice can, dump in 1 CUP of powdered fireclay, 1/2 CUP of grog, and mix it all up with a fork. This only takes a couple of minutes, and when we're done, we have enough of the mixture to make several dozen rocket motors.



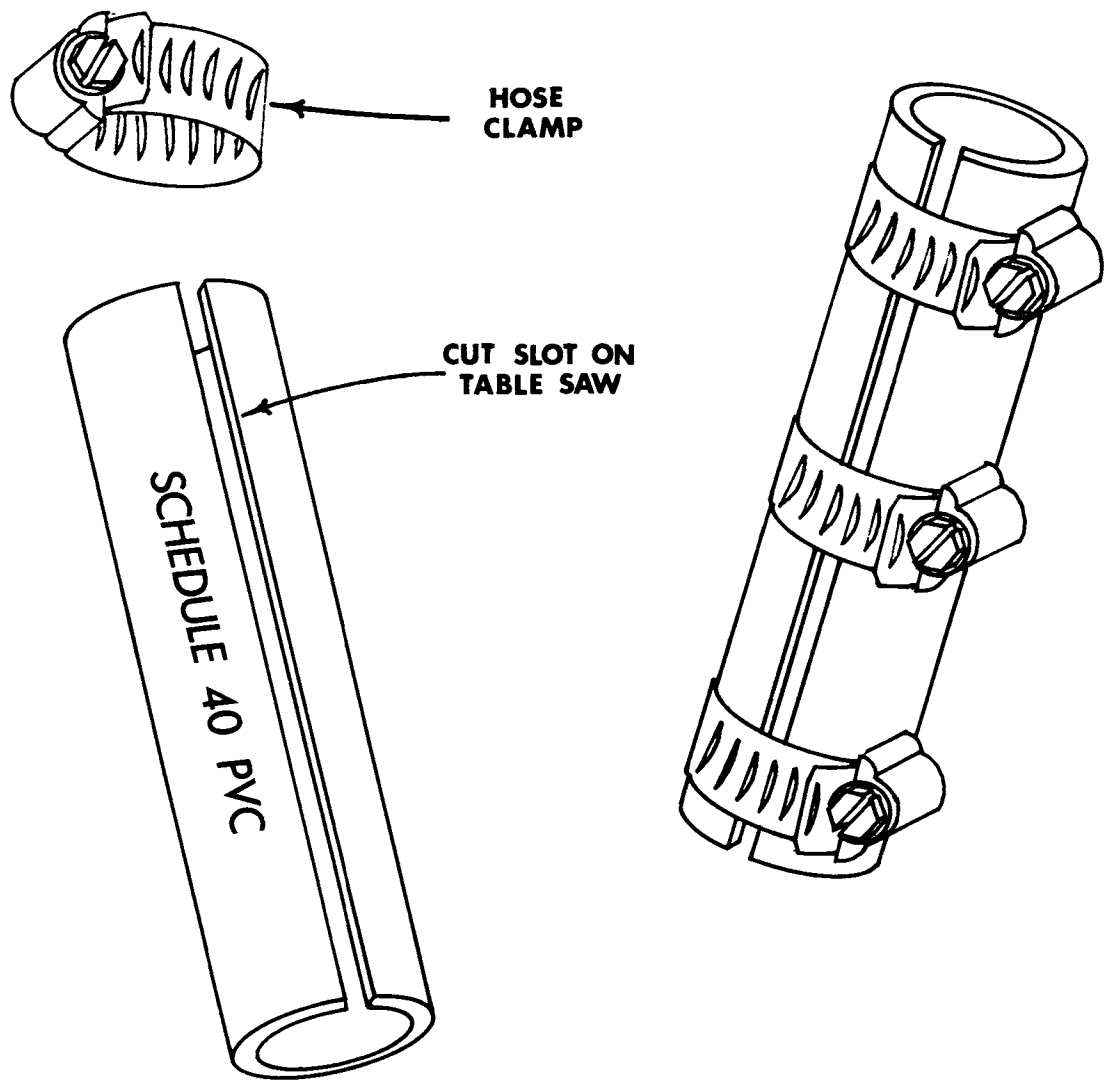
The dry fireclay normally absorbs a slight amount of moisture from the air, and this is sufficient to allow it to pack properly when rammed. If, however, the weather is hot and dry, and you have any trouble getting it to work, try moistening the mixture slightly with one or two teaspoons of water per pound.

You need four special tools to make a nozzle, and you can't buy them, so you'll have to make them yourself, or have them made by a handy friend or a machine shop.

Forming the nozzles and loading the propellant each require that you "ram" something into the cardboard engine casing. The expansive pressures generated when you do this can approach a thousand pounds per square inch.

If you attempted to do this unaided, you would simply burst the cardboard tubing. You need to wrap something around the casing to hold it together until you're finished, and so you make a tool called a CASING RETAINER. We've sketched one below.

FIGURE 5



What you're looking at is simply a piece of heavy walled, plastic water pipe with a slot cut down one side. The slot can be pinched shut or allowed to open by simply tightening or loosening the three hose clamps.

You'll need a different diameter casing retainer for each diameter of engine casing that you work with. 1-1/4 inch pipe slips neatly over our 1 inch I.D. engine casing; 1 inch pipe just fits over our 3/4 inch I.D. casing, and 3/4 inch pipe slides LOOSELY over our 1/2 inch I.D. casing. When you make the little half inch motors you'll have to wrap some kind of a shim around the casing to make it fit snugly inside the 3/4 inch I.D. plastic pipe. The shim could be cardboard, or perhaps stiff, flexible vinyl sheeting. It should be about 1/32 inch thick. In each case the casing retainer should be exactly as long as the motor that you are building.

You buy the hose clamps, but you make the retainer, itself, from a short scrap of SCHEDULE 40 PVC water pipe. Its strange name is an industrial designation understood by plumbers and building inspectors, but you can find it in any hardware store. Just be sure that you specify SCHEDULE 40 PVC.

The EASIEST way to cut the slot is on a table saw, but you COULD do it with a hand saw, and then file it out to the proper width. You'll have to arrive at the width of the slot by simple experimentation. You need to cut it just wide enough so that when you tighten the retainer around the engine casing, the slot doesn't quite pinch shut.

If you allow too wide a slot, you run into problems. When you start ramming materials into the casing, the cardboard will squeeze out along the slot. This will create a weak zone where the paper has been stretched, and when you attempt to launch your rocket the engine will rip open along this line.

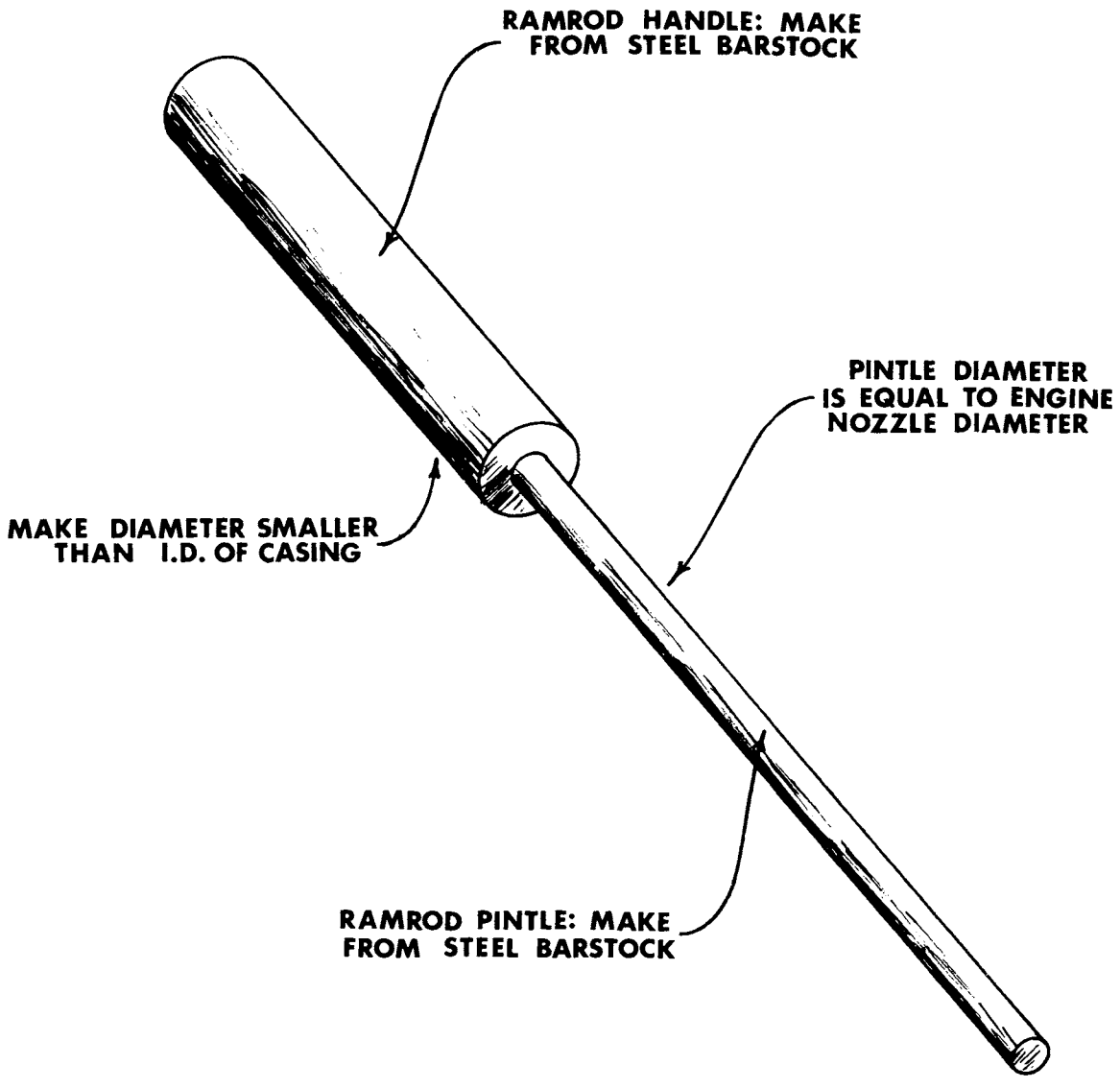
The casing retainer shown in FIGURE 5 is a small one. It has three hose clamps. Some of the larger retainers have five or six. Just understand that you need to use enough clamps to protect the casing from damage during ramming and loading. Each set of engine plans that we provide you with will tell you how big to make the CASING RETAINER, and how many clamps to use.

Your first step in building a rocket motor will be to cut a piece of kraft paper tubing to the proper length, sand the ends smooth and slip it inside of the casing retainer so that neither end sticks out (protrudes). When you saw the tubing to length, you will usually create a rough, fuzzy paper edge. You can sand this rough edge smooth with #120 grit sandpaper. If you use a belt sander, you can clean up a couple dozen casings in about five minutes.

Next, using a socket driver, or a screw driver, tighten down the hose clamps. They should be tight but not so tight that they cause the various ramrods and tamps used during succeeding steps to jam in the casing.

Now set this assembly aside and make the next required tool. It's called a RAMROD, and we've sketched one below (FIGURE 6). The RAMROD is the tool that actually compresses the fireclay-grog mixture into the form of a rocket nozzle. Each ramrod is composed of two parts, the RAMROD HANDLE, and the RAMROD PINTLE.

FIGURE 6


RAMROD HANDLE: MAKE FROM STEEL BARSTOCK
PINTLE DIAMETER IS EQUAL TO ENGINE NOZZLE DIAMETER
MAKE DIAMETER SMALLER THAN I.D. OF CASING
RAMROD PINTLE: MAKE FROM STEEL BARSTOCK

The RAMROD HANDLE is made from a length of round steel barstock. Hot rolled steel is cheaper than cold rolled, and either will work, so just use whichever is the most available. The diameter of the RAMROD HANDLE should be slightly less than the I.D. of the engine casing.

The best way to make a RAMROD HANDLE is as follows. Select a piece of barstock the same exact diameter as the I.D. of the engine casing (1" dia. for the 1" I.D. casing, and 3/4" dia. for the 3/4" I.D. casing). Cut it to the proper length, making sure that the ends are square. Then place it in a machine lathe and take a light cut, reducing its diameter by .010 to .020 inches.

Next, place the proper diameter drill bit in the lathe tailstock chuck and lathe-bore a hole in one end the same exact diameter as the RAMROD PINTLE. The hole should be deep enough to provide a firm support and guide for the pintle, and it should be deep enough to allow for the placement of a drift pin to hold the pintle in place.

If you don't have access to a lathe, simply purchase a length of barstock THE NEXT SIZE DOWN from the I.D. of the engine casing. Steel barstock comes in 1/16" increments. Use 15/16" dia. for the 1" I.D. casing and 11/16" dia. for the 3/4" I.D. casing. Reducing the diameter of the handle allows it to slide smoothly in and out of the casing without binding. When we make the little 1/2" diameter motors we use a full 1/2" dia. RAMROD HANDLE. Both are so small that we've never had a problem with binding. However, if you DO encounter difficulties, then reduce its diameter by the methods suggested above.

If you don't have a lathe, boring the hole for the pintle can be a little tricky, but if you take your time and do it carefully you should have no problem. Find the center of the round end of the handle by the best means available to you. Mark it and punch it. Then set it up vertically on a drill press table, and drill the hole exactly in the center of the punch mark. This won't be as accurate as the one done on the lathe, but it will be more than adequate. You can even do it with a simple hand drill if you can figure out a way to hold the drill square with the end of the handle.

The diameter of the RAMROD PINTLE actually determines the diameter of the rocket nozzle. This measurement is CRITICAL to the rocket's performance, so make sure that the piece of steel rod that you use is free from dents and deep scratches.

The length of the pintle is NOT critical. Just be sure that you make it long enough to slide in and out of the casing with lots of room to spare. The PINTLES on our big ramrods are about 18" long. The pintles on our smaller ones are about 12".

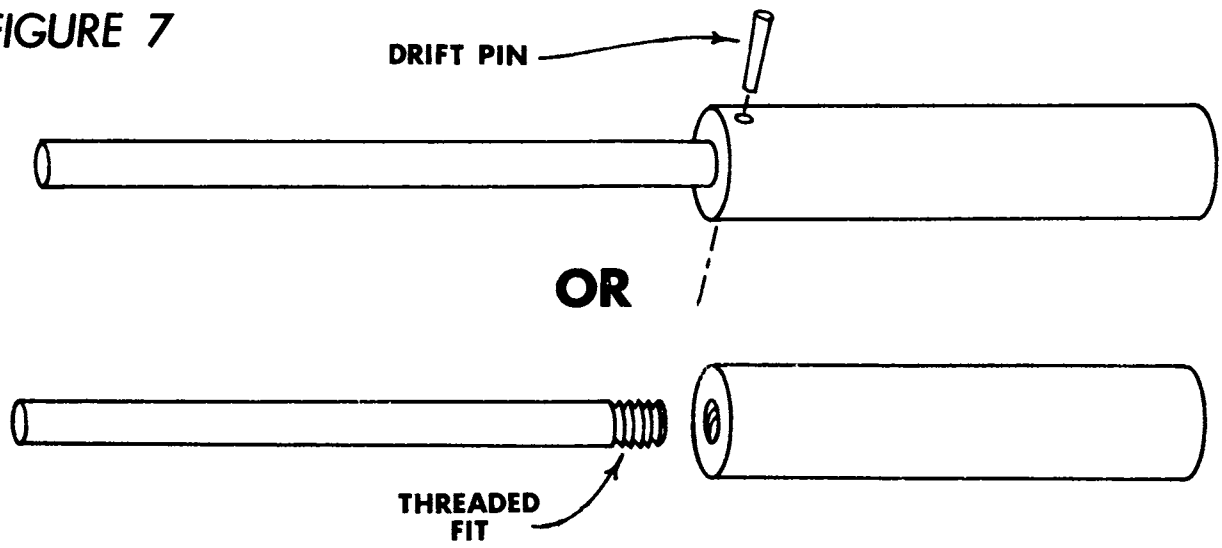
Cut a piece of rod to length, and deburr the ends. Pintles equal to or smaller than 3/8" in dia. should be firmly attached to

their handles. Pintles of larger diameter are NOT attached. They simply fit smoothly into the holes in the ends of their respective handles.

There are two ways to attach a pintle to a handle. Use whichever is the most convenient for you. The first is to use a drift pin. Insert the pintle all the way into the hole in the end of the handle. Lay the assembly on its side and drill a small hole all the way through both parts as shown in FIGURE 7. You can buy a tapered pin, or you can use a nail that's slightly larger in diameter than the hole you drilled. Drive it all the way through the handle with a hammer, clip it off, and file it flush.

The second method is to thread the end of the pintle and bore and thread the hole in the end of the handle to match. In this case, the size of the hole in the end of the handle will be smaller than the diameter of the pintle. The sizes of the taps and dies that you use will determine this measurement and your local hardware store can advise you.

FIGURE 7

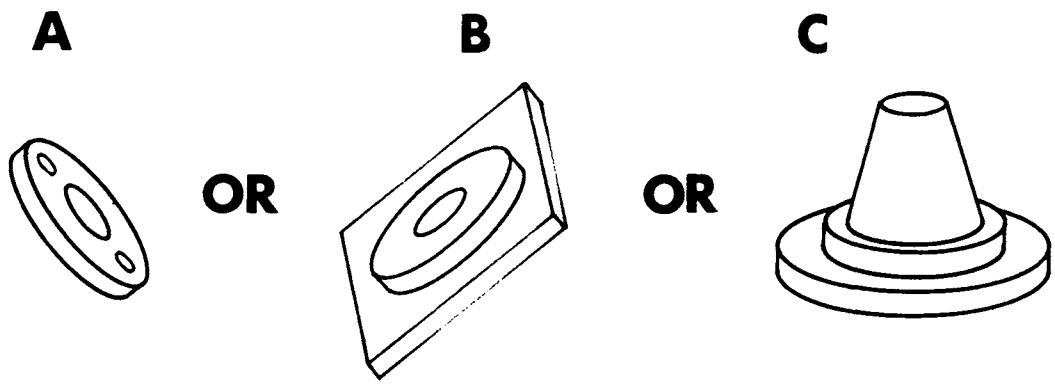


CAUTION! The RAMROD is made of STEEL. STRIKING IT WITH ANOTHER TOOL WILL GENERATE SPARKS! Never use the ramrod in the vicinity of GUNPOWDER or other EXPLOSIVES! Use it ONLY to form the rocket nozzles. NEVER use it for any other purpose!

Now make the CENTERING RING or NOZZLE FORMER. A simple centering ring centers the ramrod pintle in the engine casing and provides a surface against which to ram the ceramic powder used in forming the nozzle. A NOZZLE FORMER is much better. It actually MOLDS the ceramic into a tapered nozzle form. Rocket engines made with a simple centering ring will work just fine, but motors made with a NOZZLE FORMER will work even BETTER.

FIGURE 8 shows two centering rings and a nozzle former. The one on the left (A) is the easiest to make. You can make it out of round barstock or 1/8" to 3/16" thick steel plate. In either case, it should be made the same exact diameter as the I.D. of the engine casing.

FIGURE 8



If you make it out of round barstock, slice a round wafer off of the end of the barstock 1/8" to 3/16" thick. Make sure it's an even thickness all the way around. Grind it or file it even if necessary. Drill a hole in the center 1/64" larger in diameter than the ramrod pintle. ALL CENTERING RING AND NOZZLE FORMER HOLES ARE DRILLED 1/64" LARGER IN DIAMETER THAN THEIR RAMROD PINTLES. This allows the pintles to slide smoothly in the rings without binding.

Next drill a shallow hole on each side of the main hole. DON'T drill all the way through. When you're finished with the rocket motor you can grip these two holes with a pair of needle nose pliers and remove the ring from the casing.

The ring in the center (B) is easier to handle. To make this one you use a welding rig and brazing rod to "braze" the wafer to a piece of sheet steel. File or grind away the excess brass, and THEN drill the hole for the pintle. When you want to remove the ring from the casing this sheet steel flange gives you something to hold on to.

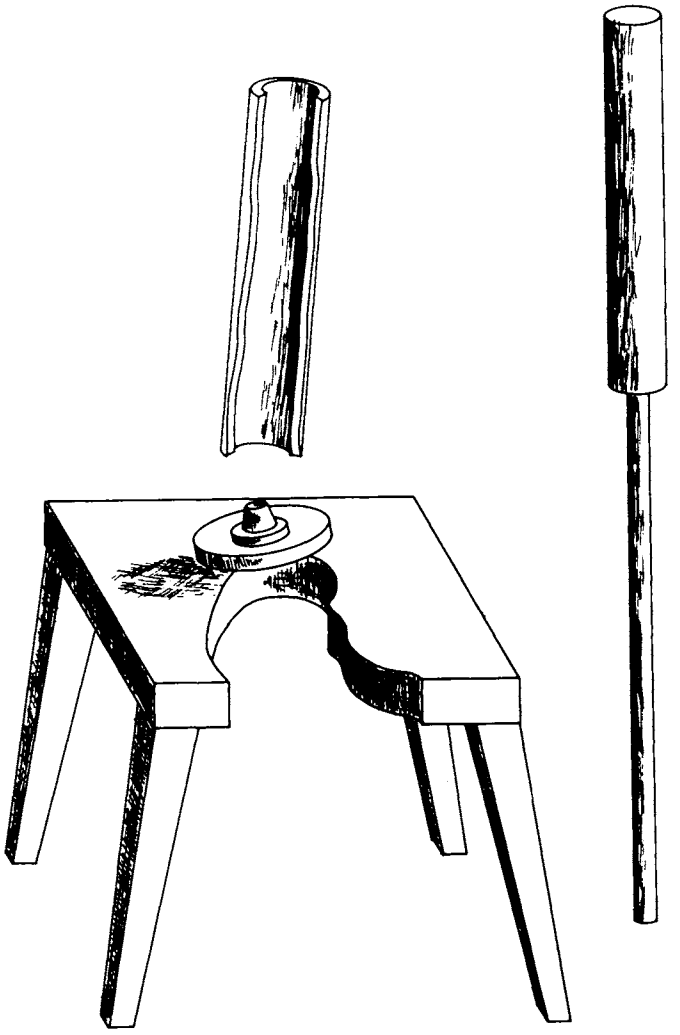
The illustration on the right (C) is the BEST way to do the job. It's an actual NOZZLE FORMER, and you need a machine lathe to make it. Each set of engine plans will provide mechanical drawings that will show a machinist how to make the particular nozzle former required. The expanding exit taper aids in the expansion of rocket exhaust gases, thus lowering back pressure and

increasing gas exit velocity. This raises thrust significantly and makes for much better rocket performance.

With the completion of these tools you're ready to actually make a nozzle. FIGURE 9 shows a RAMROD, a NOZZLE FORMER, and a cut-away view of an engine casing. We've placed a little "token" workbench in the scene and drawn it as though a portion of its top had been jigsawed away. In reality, there is a hole drilled in the top of the workbench for the RAMROD PINTLE.

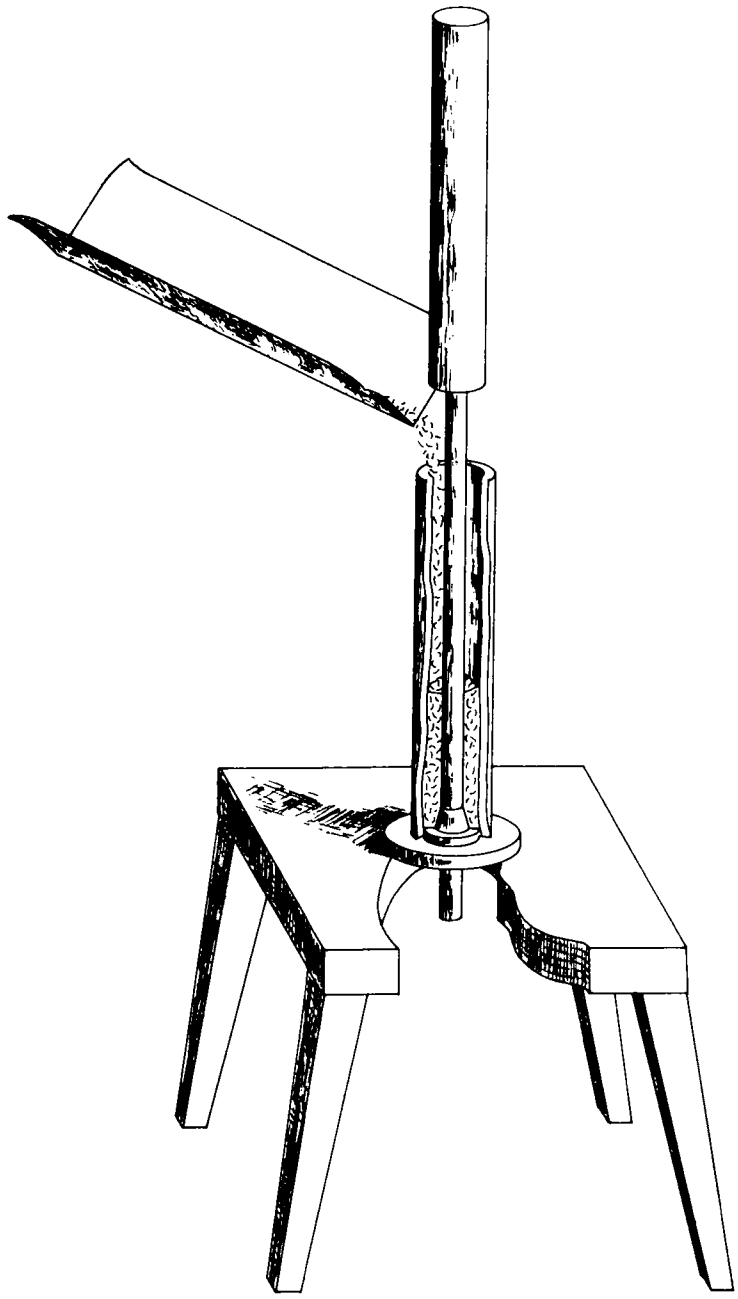
You'll notice immediately that the CASING RETAINER is missing. We eliminated it from these drawings so that it wouldn't get in the way of our illustrations. Just remember that THE CASING RETAINER MUST BE IN PLACE DURING ALL RAMMING AND LOADING OPERATIONS.

FIGURE 9



Place the NOZZLE FORMER over the hole in the workbench surface; place the kraft paper engine casing (with CASING RETAINER, not shown) over the NOZZLE FORMER and insert the RAMROD through the hole in the NOZZLE FORMER. FIGURE 10 shows the next step. Raise the Ramrod enough to get the handle out of the way, and using a paper trough, fill the casing with a measured amount of the dry fireclay-grog mixture.

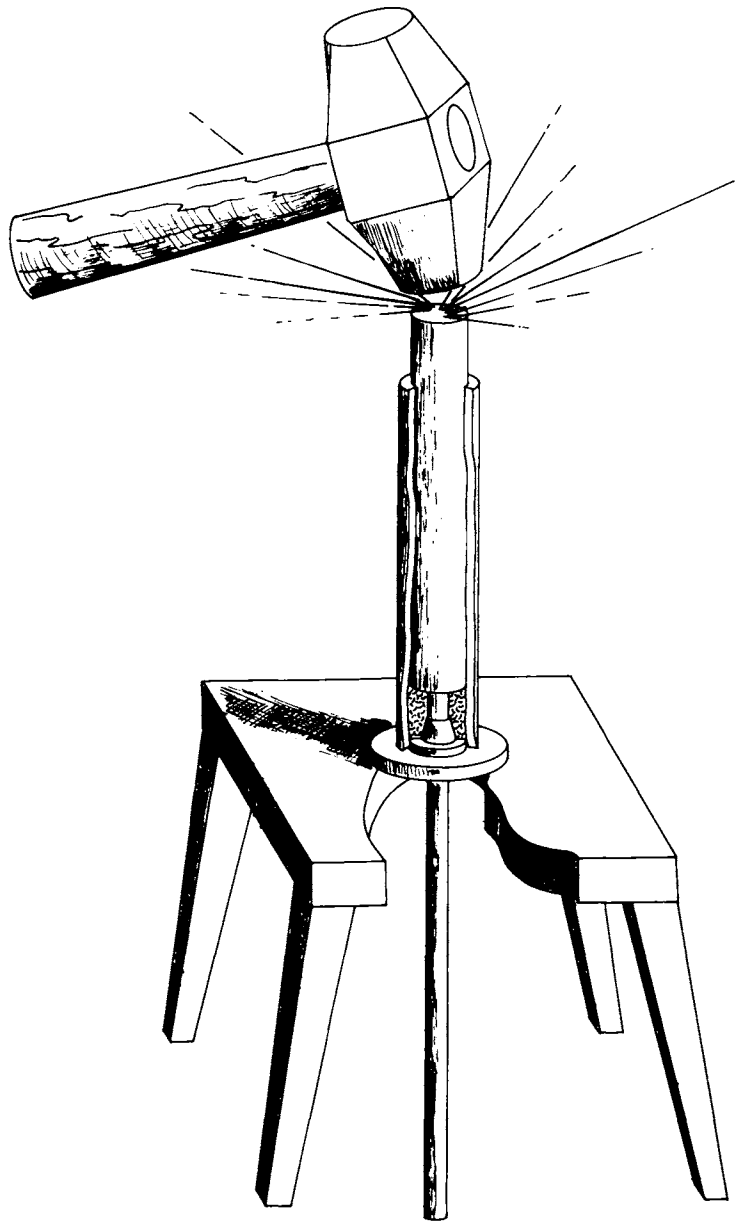
FIGURE 10



Each size of nozzle or casing takes a different amount of the ceramic powder, and you'll have to do a little experimenting to arrive at the exact amount in each case. However, each engine plan will provide you with an approximate amount to use as a starting point.

Next, using a hammer or sledge of the proper size (FIGURE 11), drive the ramrod down into the engine casing, compressing the ceramic powder against the nozzle former. Use a 20 oz. ball peen hammer for the 1/2" I.D. motors, a 2 lb. sledge hammer, or "single jack" for the 3/4" casings, and a 6 lb. or 7 lb. sledge head on a short handle for the big 1" motors. In each case, the hammers should be wielded from the wrist.

FIGURE 11

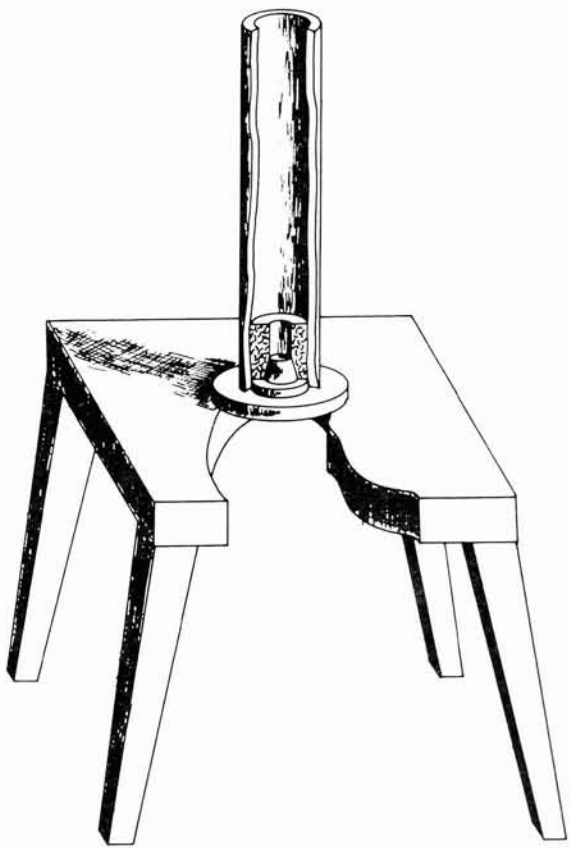


It takes several solid hits to accomplish this. The powder will at first feel soft, but will yield less and less with each blow. After four or five blows it will "harden up".

FIGURE 12 shows the casing and nozzle former with the ramrod removed. Actually, you'll have to lift them from the workbench and separate them with a firm pulling and twisting motion. This can be a bear of a job unless you've remembered to do the following. Before inserting the ramrod into the nozzle former or pouring the ceramic into the casing, coat the ramrod pintle with NON-STICK VEGETABLE COOKWARE COATING. You can buy it in any grocery store. It's the stuff that you spray on your frying pan to keep the eggs from sticking. It will lubricate the pintle and make separation much easier.

For all but the largest pintles and casings we can make the following statement with a fair amount of certainty. If the ramrod is REALLY STUCK you've hammered it in a lot tighter than it has to be. Go easier the next time.

FIGURE 12



Pintles larger than 3/8" dia. WILL be difficult to remove, so instead of connecting the pintle to its handle with a drift pin or thread, you leave the two unattached. Apply a tiny piece of vinyl electrical tape to the end of the pintle that fits into the handle. This should provide enough friction to hold the pintle in place while you raise it up to pour the ceramic into the engine casing.

After compressing the ceramic, pull and twist the handle lightly. It should come right out of the casing, leaving the pintle behind, stuck in the nozzle. Next, place a rod slightly smaller than the nozzle against the end of the pintle in the casing, and using a few light hammer taps, drive the pintle out of the nozzle without damaging it. A shallow hole drilled in the handle end of the pintle will aid in locating the driving rod.

Once the ramrod has been removed the nozzle is finished, and with the exception of "trimming", the casing is ready to be loaded with propellant.

As stated earlier, all the motors described in this manual are CORE BURNERS. The propellant CORE is formed around a tool known as a CORING PINTLE. You make each coring pintle a specific length. Since the propellant and hence the propellant core begin where the nozzle throat ends, the LENGTH of the nozzle throat determines the length of the core. The LENGTH of each nozzle throat is CRITICAL. Therefore, you must make sure that for a particular coring pintle, your nozzle throats will always be the same length.

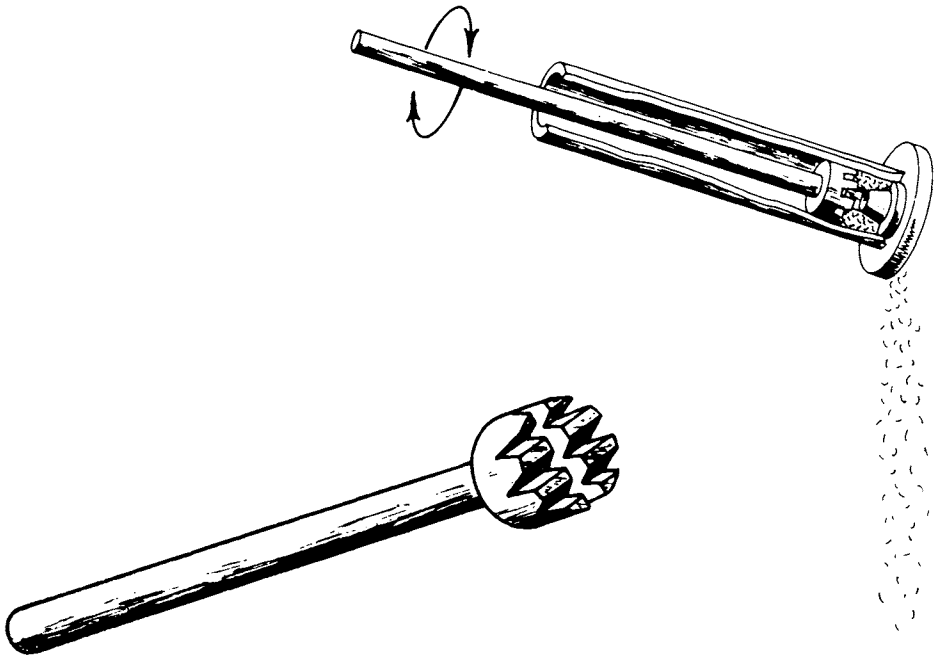
When you poured the ceramic powder into the casing and formed the nozzle you should have, ideally, used exactly the correct amount. More than likely, you didn't. You probably added too little or too much. If you added too little, simply reinsert the ramrod and ram a little more of the fireclay-grog mixture into the casing to make up for the shortage. If you put too much in originally, you've made the throat too long, and you must trim it back.

You do this with a tool called a NOZZLE TRIMMER. FIGURE 13 shows a nozzle trimmer, and shows it in use inside an engine casing. To make the NOZZLE TRIMMER you cut a thick "biscuit" off the end of a piece of steel barstock. The length of the biscuit should be equal to the diameter of the barstock, and the diameter of the barstock should equal the inside diameter of the kraft paper engine casing.

Next drill a 1/4" dia. hole in the round end of the biscuit. Center it well, and drill it to a depth equal to about half the length of the biscuit (1/2" for the 1" I.D. casing, and 1/4" for the 1/2" I.D. casing). Cut a one foot length of 1/4" dia. steel rod and insert it into the hole. Affix it to the biscuit by a drift pin or by brazing.

Using a hacksaw, metal cutting bandsaw, or an abrasive disc, cut a WIDE and DEEP "waffle" pattern into the end of the biscuit. The trimmer is now finished.

FIGURE 13



To trim a nozzle back, insert the nozzle trimmer into the casing and with a twisting motion, use the waffle head to grind away the excess ceramic. Some of the residue will fall out through the nozzle, and the rest will stick in the waffle. You'll have to clean it out with a toothpick or a pocket knife. If you placed the trimmer in an electric hand drill, you can accomplish the grinding in "nothing flat".

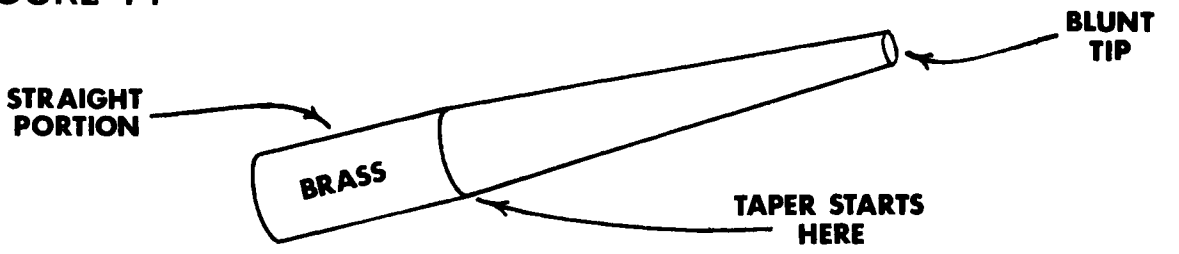
If you used the NEXT STEP DOWN method of making your ramrod handle, then there will be quite a gap between the handle and the walls of the casing. When you compress the ceramic against the nozzle former, a lot of the powder will squeeze up around the ramrod handle, thus rendering any powder measurement inaccurate.

However, if you make the handle on a lathe, removing only enough metal to keep it from binding in the casing, there will be virtually no room for the powder to escape. If you combine a ramrod constructed in this way with some accurate weighing equipment, i.e. a good gram scale, you should be able, with a little practice, to completely eliminate the need for the trimmer.

LOADING THE PROPELLANT

Before you can load the propellant you must make a tool called a CORING PINTLE. It's VERY simple to make, and we've sketched one below (FIGURE 14).

FIGURE 14



You must obtain a piece of BRASS rod the EXACT, SAME diameter as the ramrod pintle. ALL CORING PINTLES ARE MADE OF BRASS! We can't emphasize this enough! NEVER make the coring pintle out of steel. ALWAYS USE BRASS!

The coring pintle fits through the hole in the nozzle former during loading and tamping operations. It is straight and equal to the diameter of the ramrod throughout this portion of its length. It extends about 1/4" into the compressed gunpowder, from which point it tapers to a blunt point toward the front of the engine.

Each model of rocket engine requires the use of its own unique coring pintle. When you load and tamp the propellant into the engine casing, it packs around the coring pintle. When the pintle is removed, it leaves behind it a hollow, tapered core of specifically engineered dimensions. Each engine plan we provide will contain a drawing of the coring pintle along with its exact dimensions.

The easiest way to make a coring pintle is to cut a piece of BRASS rod of proper diameter to the proper length. Mark a ring in pencil where the taper is to begin. Chuck it into an electric hand drill, and with the drill running, hold the pintle against a running belt sander or grinding wheel until it has been sanded to the proper taper.

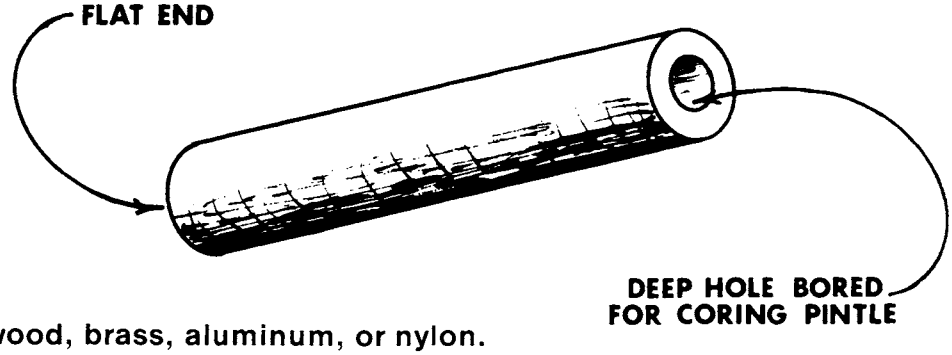
You must also make a tool called a TAMP. The tamp is used to actually compress the loose gunpowder into the engine casing. You can make an experimental tamp out of a hardwood dowel, but for continued use it won't hold up. Brass and aluminum will work better, but the striking end of a tamp made from either metal will mushroom after a while.

Go to the Yellow Pages once again, and look up PLASTICS. Any place that sells plastics will either have in stock or be able to order round NYLON barstock. Nylon is one of the toughest substances ever made by man, and after you've used a nylon tamp for a while, you'll understand its merits. You can absolutely "murder it" with a sledge hammer, and it will bounce right back.

FIGURE 15 is a sketch of a tamp. It is actually two tools in one. One end of it is a CORED TAMP, and the other end is a FLAT TAMP. The cored end is used for packing the gunpowder around the coring pintle, and the flat end is used to pack the delay charge in the front of the motor.

FIGURE 15

WARNING! Do NOT make this tool out of steel or iron!



Use ONLY wood, brass, aluminum, or nylon.

The tamp required for the large 1" I.D. engine casings should be about one foot long. The tamp for the 3/4" I.D. casings should be 8" long, and the tamp for the 1/2" casings, about 6" long.

Purchase a length of round NYLON barstock (or wood dowel) equal in diameter to the inside diameter of the kraft paper engine casing. The tamp MUST be reduced in diameter by about .020", or it will jam in the casing when you try to use it. If you're using wood, brass or aluminum, you can sand or grind it down. If you're using nylon, you'll have to machine it down on a lathe (it will melt if you try to sand it).

After you've machined it to the proper diameter and cut it to the proper length, you must bore a DEEP hole in one end. The hole should be the same diameter as the nozzle, and about the same depth as the propellant core.

Once again, the best way to bore the hole is on a machine lathe, but you CAN do it on a drill press IF YOU ARE CAREFUL. For the 1/2" diameter casing tamps, you can use a standard high speed steel drill bit. For the larger diameter tamps with deeper holes use an IRWIN SPEEDBORE, also called a "spade boring bit". They are specifically designed for wood but will work beautifully with nylon. They have extremely long shanks, and in the larger sizes are much cheaper than standard drill bits. You can find them in any large hardware store.

FIGURE 16 illustrates the first step in loading the propellant. The coring pintle is inserted through the nozzle former, and the

FIGURE 16

entire assembly with casing retainer (not shown) is placed back on the workbench. You'll have to set it to one side of the ramrod hole. The coring pintle must at all times be supported by the workbench surface.

MAKE SURE THAT THE EXPLOSION SHIELD IS IN PLACE, and proceed to the next step.

Before you can use the gunpowder IT MUST BE DAMP. We dampen it in batches of one or two pounds at a time, but you can prepare whatever amount suits you.

ADD 8 TEASPOONS WATER PER POUND

This amount of water gives the gunpowder a 8-1/2% moisture content. Any more or less and it won't pack properly. You can interpolate these figures for different batch sizes, but DON'T dampen more than you can use in about an hour. When you let it sit around it DRIES OUT.

You'll need a big plastic bowl with a tight fitting lid. Pour ONE POUND of the dry gunpowder into the bowl. SPRINKLE 8 teaspoons of water on top of the powder. The water will "bead up", so fold it gently under the powder with a big spoon or spatula. Scrape any powder and water that sticks to the spoon back into the bowl and replace the bowl's lid.

Holding the lid tightly in place, shake the bowl vigorously for several minutes. As the moisture is distributed throughout the mixture, the powder will become "sticky". When you remove the lid, some of the powder will stick to the lid and the sides of the bowl. Scrape this powder back into the bowl.

With the back of a table fork (the kind you eat with) press some of the powder against the smooth inside of the bowl, and draw it away. The powder will stick to the back of the fork and present a smooth surface for inspection.

It will at first appear blotchy (dark and light patches). The dark patches are wet, and the light patches are dry. This indicates that the moisture is not yet EVENLY distributed.

Using the back of the fork, and periodically rotating the bowl, "knead" the powder against the sides of the bowl for several minutes. Check the appearance of the powder periodically. When the smooth inspection surface on the back of the fork appears a reasonably uniform grey, the powder is ready to use.

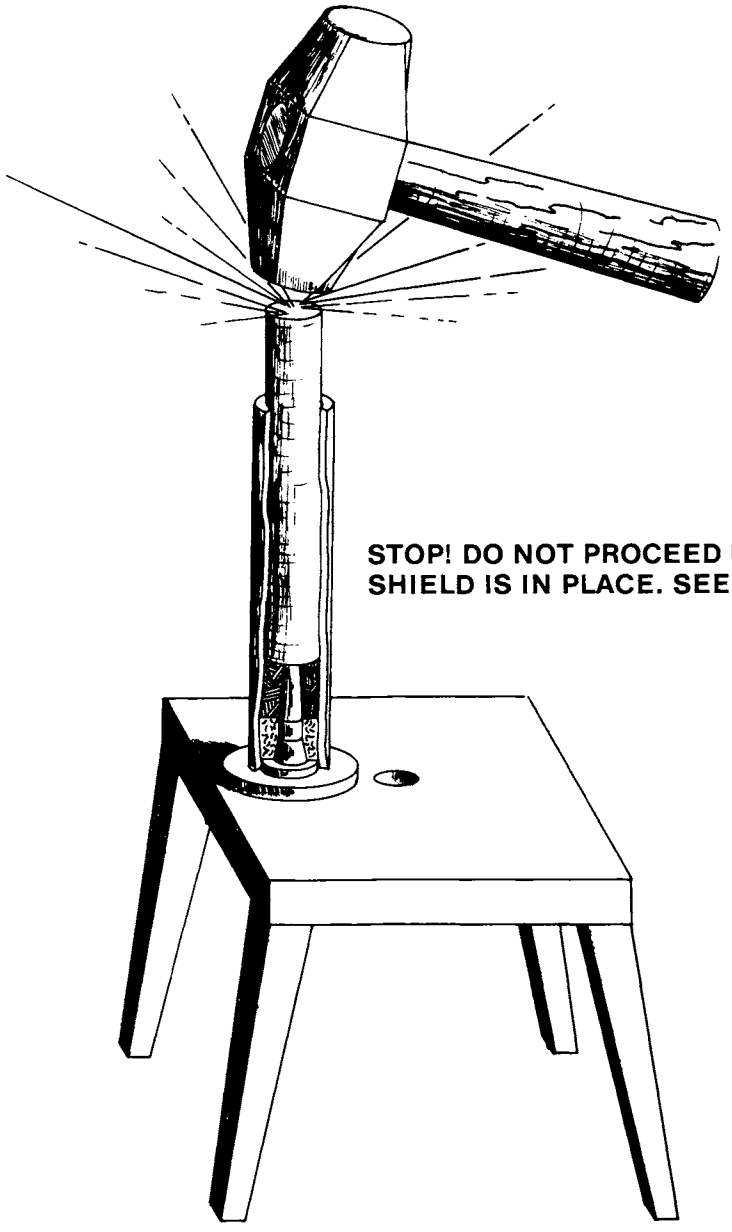
This entire operation shouldn't take more than five minutes or so. If it does, you're probably carrying it further than you have to.

Weigh out the proper amount of this dampened propellant and pour a portion of it into the engine casing. We use a plastic kitchen funnel, and when the powder sticks in the funnel, we poke it through with a pencil or a stick.

You can't load and tamp all of the powder at once. You have to split it up into doses. For the tiniest 1/2" engines we load it in about 4 doses, and for the largest motors, we use 10 or 12.

FIGURE 17 shows the next step. Insert the cored tamp into the

FIGURE 17



STOP! DO NOT PROCEED UNLESS EXPLOSION SHIELD IS IN PLACE. SEE INTRODUCTION!

engine casing on top of the loose gunpowder, and using the same size hammer that you used to make the nozzle, compress the powder down around the coring pintle. For the tiniest engines it will take 3 or 4 good solid hits. For the giants, 6 to 8. You'll catch on to the feel of it fairly quickly. It's not as critical as you might think.

Some of the powder will get stuck up inside the core of the tamp. To dislodge it, place your finger over the core hole and strike the tamp sharply on the workbench. Remove your finger, and pour the loosened powder back into the engine casing.

FIGURE 18

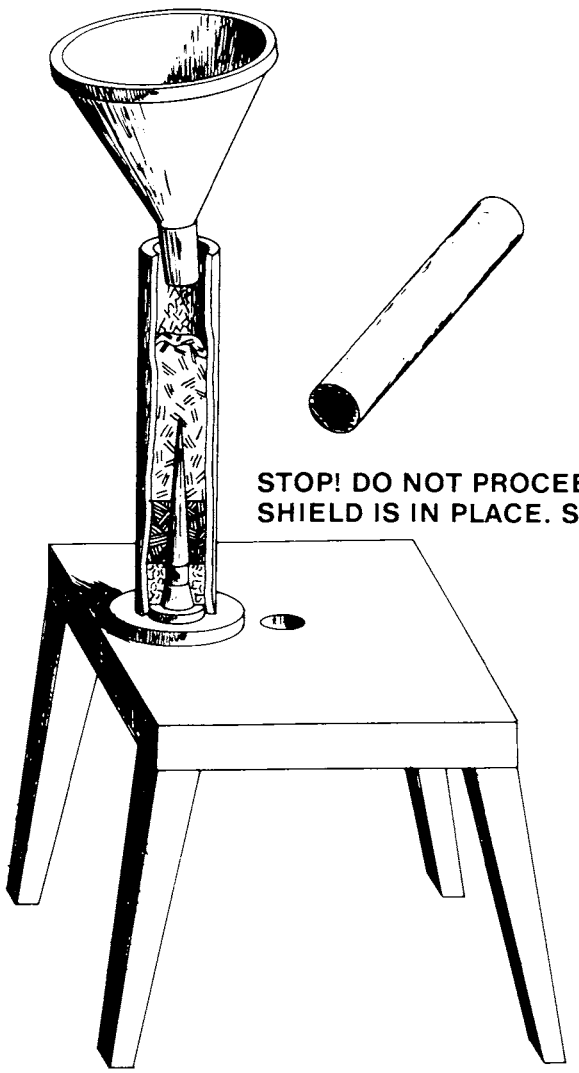
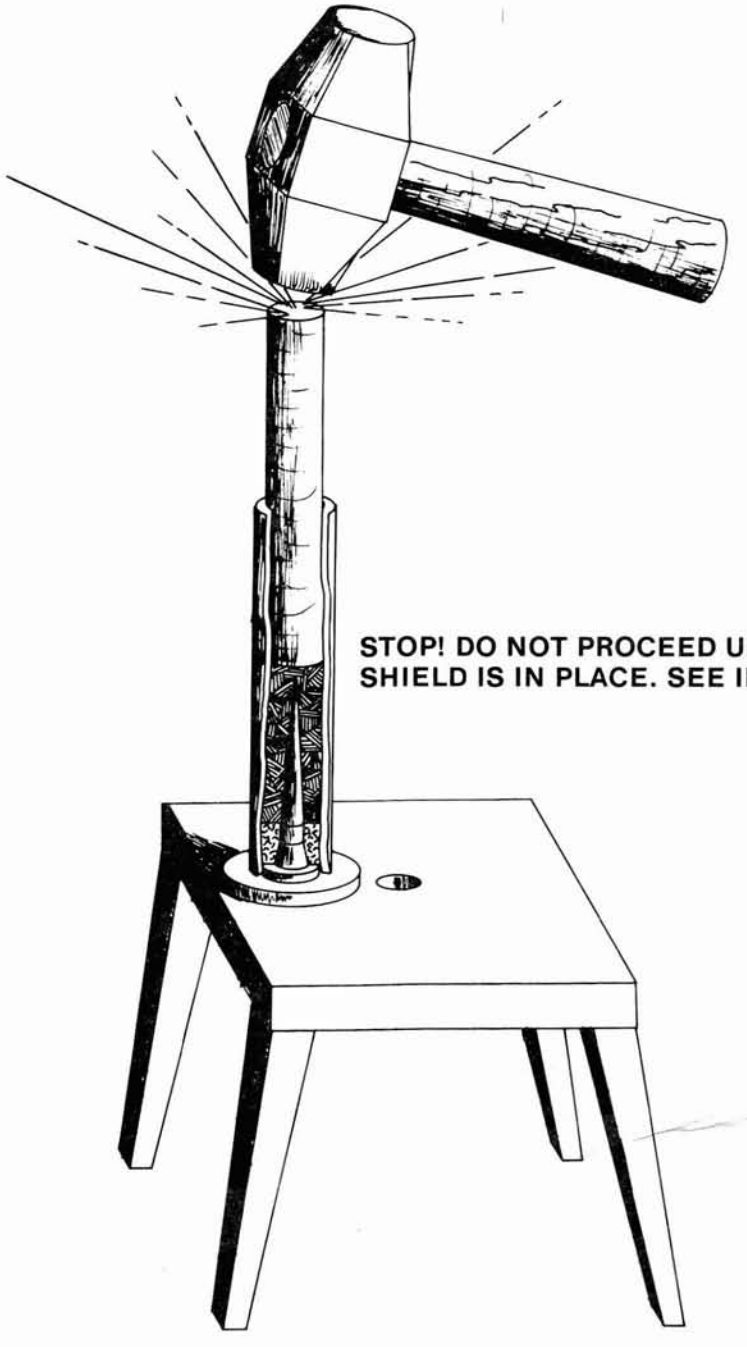


FIGURE 18 shows the tamp removed and the next dose of powder being poured in. This time, from experience, we know that when the powder is compressed, its upper surface will end up beyond the tip of the coring pintle. For this reason, we no longer need to use a cored tamp, and so we turn the tool over and use its flat end. Once again we use the hammer and tamp to compress the powder firmly into the casing (FIGURE 19).

FIGURE 19



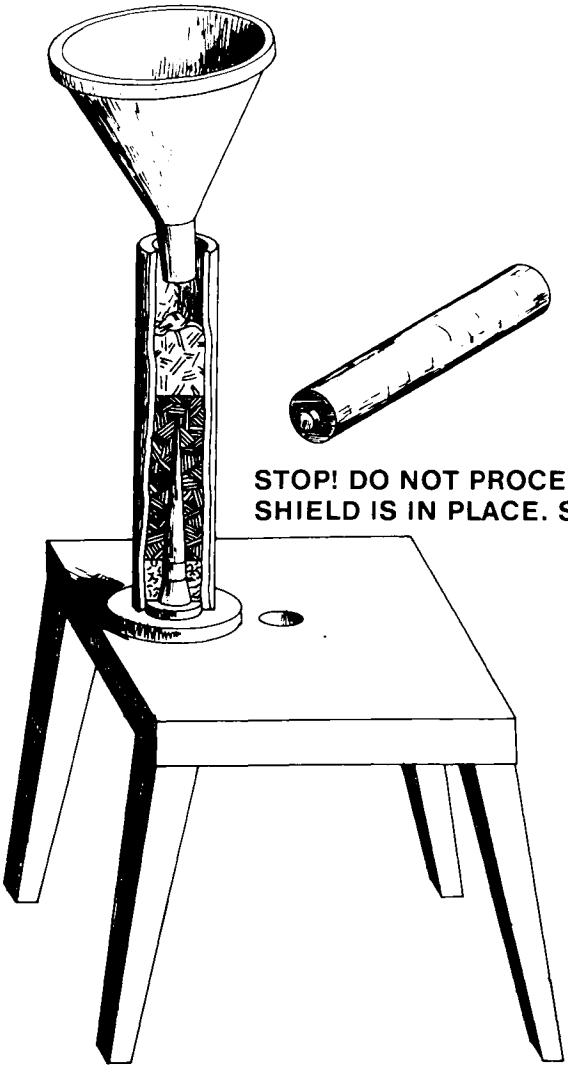
STOP! DO NOT PROCEED UNLESS EXPLOSION SHIELD IS IN PLACE. SEE INTRODUCTION!

FIGURE 20 shows the flat tamp removed and the final dose of powder being loaded. If the motor were a second or single stage version with a small nozzle, we would once again use the flat tamp to drive home the last bit of propellant.

In this case, however, we are making a booster engine, and it must have a STAGING DIMPLE in the end of the propellant charge. To accomplish this we use a DIMPLING TOOL instead of the flat tamp.

As we will show you in the last section of the book, a soda straw or cocktail straw is inserted into the staging dimple and filled with loose powder, which ignites the second stage engine. The

FIGURE 20



STOP! DO NOT PROCEED UNLESS EXPLOSION SHIELD IS IN PLACE. SEE INTRODUCTION!

staging dimple should be just a little smaller in diameter than the soda or cocktail straw so that the straw fits tightly. To make the dimpling tool, simply make another flat tamp. Obtain a piece of brass, wood or aluminum slightly smaller in diameter than the chosen straw.

Most soda straws are 1/4" in diameter. Select a piece of brass rod 1/4" in diameter, and grind or sand it down JUST A BIT. Next drill a hole in the end of the tamp a little smaller than the brass rod. Hammer the brass rod into the hole and cut it off to length. It should stick about 3/16" beyond the end of the tamp.

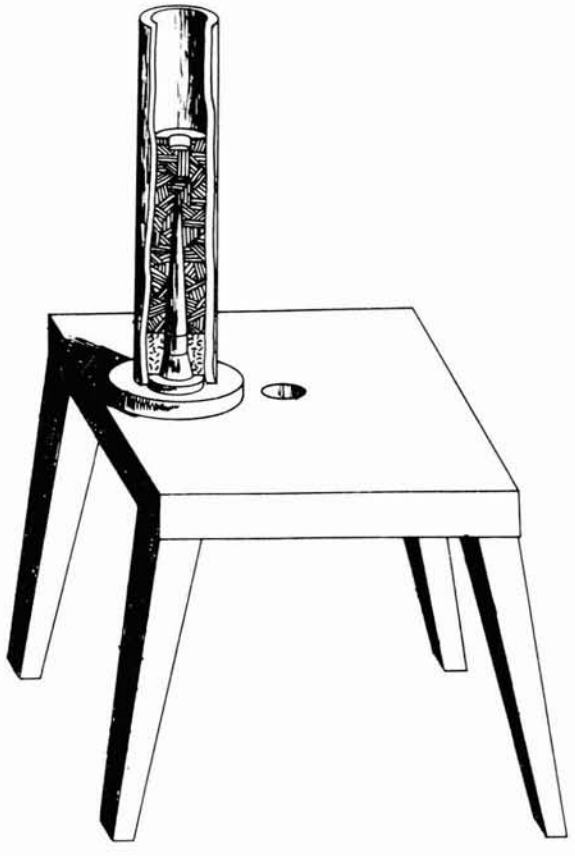
FIGURE 21

STOP! DO NOT PROCEED UNLESS EXPLOSION SHIELD IS IN PLACE. SEE INTRODUCTION!

FIGURE 21 shows the hammer and dimpling tool being used to form the front end of the booster.

FIGURE 22 just below shows the engine casing, nozzle former, and coring pintle with the dimpling tool removed.

FIGURE 22



Pick the assembly up from the workbench, and with a twisting motion (FIGURE 23) remove the nozzle former from the end of the casing. The coring pintle will remain stuck in the compressed propellant charge.

Using a pair of pliers, pull with a twisting motion on the coring pintle to remove it from the finished motor (FIGURE 24). We use a pair of automotive ball joint pliers for this purpose. They have

a half round channel machined into each jaw that makes them perfect for gripping the pintle.

Loosen the clamps; remove the finished engine from the casing retainer (not shown), and you're done!

There is a little artistry in all this, and you'll probably feel clumsy at first. With an afternoon or so of practice you'll become much more efficient, and soon you should be able to make a half dozen to a dozen motors in an hour, depending on their size.

FIGURE 23

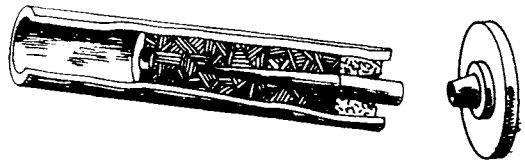


FIGURE 24

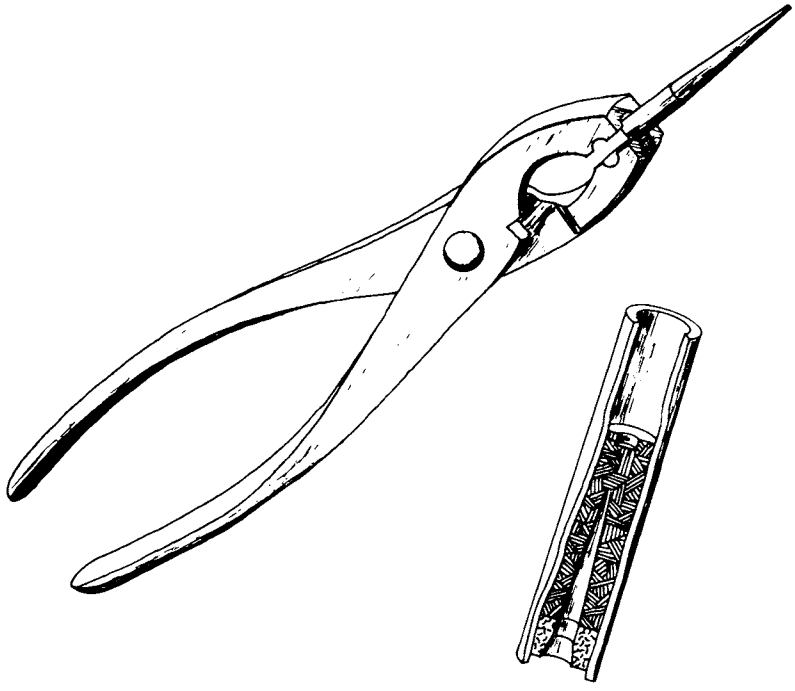
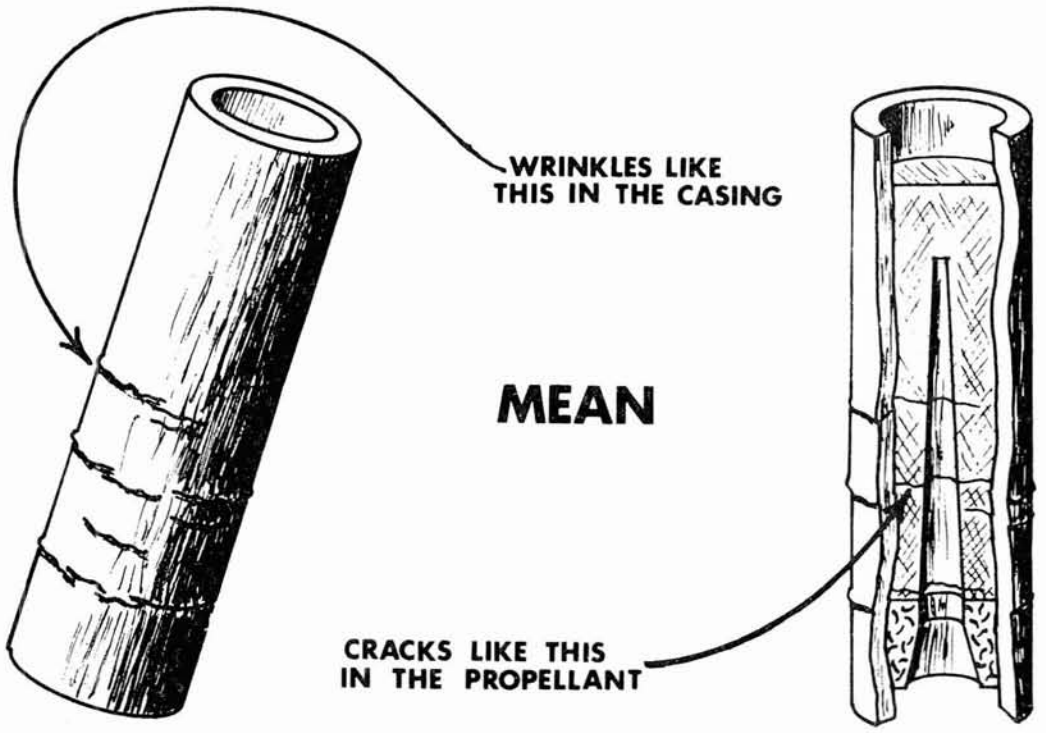


FIGURE 25 illustrates an exterior view and a cutaway view of a finished rocket motor. You'll immediately notice something wrong with it. Every time you remove an engine from the casing retainer, give it a brief inspection.

FIGURE 25



When you ram the ceramic and the gunpowder into the rocket casing, make sure that the casing retainer is GOOD AND TIGHT. Otherwise the kraft paper casing will be compressed down into the retainer like a loose stocking sliding down into a high ankled hiking boot. This will cause wrinkles to develop around the circumference of the motor casing.

A SLIGHT amount of wrinkling around the lip of the nozzle is normal. This is where the casing rested on the workbench. ANY OTHER WRINKLING in ANY OTHER AREA is INTOLERABLE! WRINKLES IN THE CASING MEAN CRACKS IN THE PROPELLANT, and propellant cracks are UNREPAIRABLE. If you attempt to launch a motor with a cracked propellant charge, IT WILL EXPLODE!

If you have any doubts about a particular engine, shine a bright light into the propellant core. Clean it out if necessary with a dry cotton swab, and give it a good inspection before attempting a launch. If it proves to be defective, destroy it by soaking it in water.

If you're SURE that you've tightened the casing retainer securely, but you STILL get wrinkles and propellant cracks, then you're ramming the powder in TOO HARD! Go easier the next time.

A lot of these motors look alike, and it's easy to get one mixed up with another. Each time you finish an engine, write on it the date that you made it and what it is. This will prevent both surprises and disappointments on the launch pad.

CURING THE MOTORS

If you're anxious to try one of these motors out, you might want to tape it to a guide stick, tape on a paper nose cone, and launch it immediately. It will fly pretty well. However, all of these motors have been engineered to be fired DRY. To function at its fullest potential, the propellant must be thoroughly CURED. Once a motor is fully cured, its power and thrust will QUADRUPLE! That is, a motor that registers 3 pounds of thrust just after you've made it will generate 12 POUNDS OF THRUST when it's completely dry!

The easiest and SAFEST way to accomplish this is by simple air drying. If you live in a warm and dry climate, the little ones will take about 4 days. The one inch engines will take a couple of weeks. If you live in a cool and damp climate, the drying time could be double or triple the figures just mentioned.

If you DO air dry your engines, NEVER PLACE THEM IN THE DIRECT HEAT OF THE SUN! ALWAYS keep them in the SHADE. If you allow the temperature of the damp propellant to rise much above 110 degrees Fahrenheit, it will SWELL and CRACK!

When you mix water with the gunpowder it actually dissolves a significant proportion of the potassium nitrate. When the water evaporates, that percentage of the nitrate recrystalizes, forming a chemical cement that renders the propellant charge "hard as a rock".

Under proper conditions water evaporates slowly from the surface of the propellant charge. A physical phenomenon called "capillary action" draws further moisture into the dehydrated area. A continuous migration of water molecules from the inside to the outer surface takes place until ALL of the free moisture has escaped.

This continual remoisturization of the surface allows a small percentage of the potassium nitrate to remain in solution until the end of the process, thus providing a pathway that allows the migrating moisture to dissipate.

IF, however, the propellant is allowed to get TOO HOT, rapid evaporation of water on the surface of the charge allows ALL of the potassium nitrate in this area to crystalize. This process is called "case hardening", and once it occurs it presents a dense barrier to the escape of any remaining moisture.

At the same time this case hardening is taking place the excessive heat in the interior is causing moisture and minute amounts of trapped air to expand. Having no way to get out, these expanding materials build up pressure and eventually bloat and split the propellant charge.

When the propellant is contained in an engine casing the phenomenon can be difficult to spot, so when we initially suspected the nature of the problem, we rammed some of the dampened gunpowder into a piece of plastic water pipe. With a wooden dowel we then forced the compressed charge out of the pipe, obtaining a solid cylindrical pellet of rocket propellant.

We subjected this pellet to a temperature of 140 degrees Fahrenheit, and lo and behold, it bloated and split open like a rising loaf of bread dough.

When this happens to one of your rocket motors, THERE IS ABSOLUTELY NO WAY TO REPAIR IT, and you should destroy the defective engine by soaking it in water. If you attempt to launch such a rocket motor, IT WILL EXPLODE!

As we told you to do on page 42, you should carefully inspect the finished propellant core of EVERY rocket engine you make. If you see ANY cracks, the engine MUST be DISCARDED.

Air drying works fine if you live in a dry climate. HOWEVER, if you happen to live in SEATTLE, WASHINGTON, and it's JANUARY, and it's RAINING in TWO directions at once, you probably won't be too successful. In such a situation it is even conceivable that your motors might pick up EXTRA MOISTURE out of the air!

The only solution to this problem is to dry them ARTIFICIALLY. To do this we went out and bought a commercially made food dehydrator. It cost $120 on sale, but BOY, does it do a BEAUTIFUL job! It has a thermostatic control on the front, and we set it for 105 degrees Fahrenheit. It has a concealed heating element and a little fan that blows a steady breeze of warm air across the damp rocket motors.

The smallest engines dry within 24 hours. The biggest ones take 48 to 72. When they're finished we store them two or three at a time in zip-lock plastic bags, and we NEVER store more than a few in any one place. Since these engines have hollow cores, they're a little more fragile than the commercially made end-burners. The longer and larger ones can be easily cracked by dropping them onto a hard surface, and of course, once they're cracked they must be discarded.

WARNING: NEVER USE ONE OF THE CHEAP DEHYDRATORS THAT WORKS WITH A LIGHT BULB OR AN EXPOSED HEATING ELEMENT! NEVER USE A DEHYDRATOR THAT DOESN'T HAVE AN ACCURATE THERMOSTAT! NEVER USE A DEHYDRATOR LOADED WITH ROCKET ENGINES INDOORS, and ALWAYS PLACE YOUR DEHYDRATOR IN A PROPERLY SANDBAGGED FORTRESS DURING OPERATION!

MULTISTAGE IGNITION

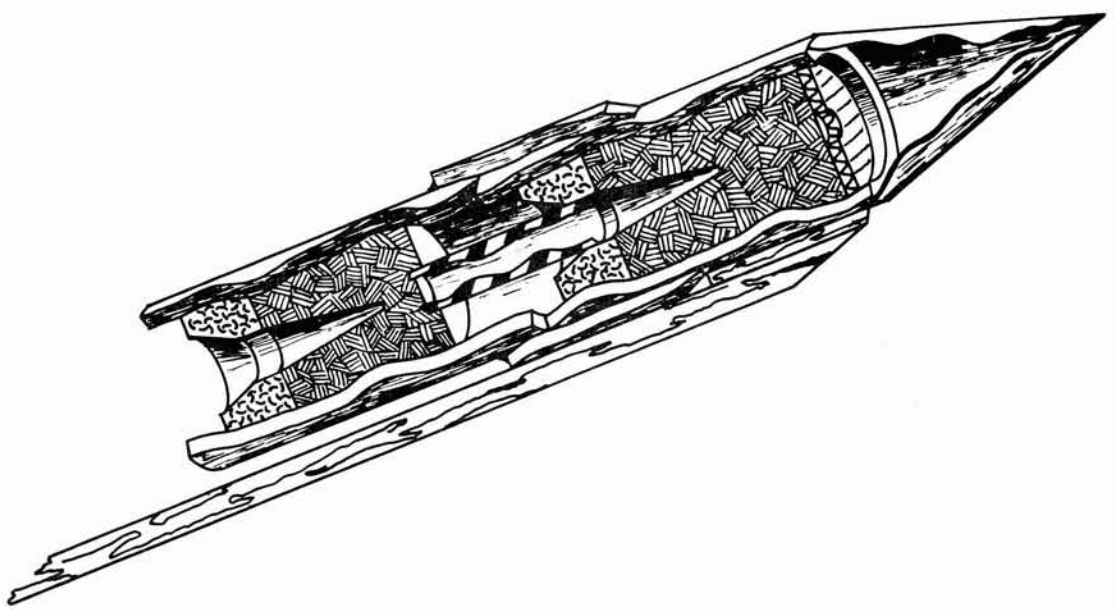
A properly designed two stage rocket uses its booster engine to lift it off the ground and accelerate it to several hundred miles per hour. When the propellant and thrust run out, the missile begins to decelerate.

AT THIS EXACT MOMENT, before the rocket has a chance to lose much velocity, the last remaining bit of booster propellant ignites a charge of flashpowder, which in turn ignites the second stage rocket engine.

In most model rockets the second stage fits smoothly but snugly into the first, like a dart in a blow gun. When the second stage engine ignites, the sudden increase in pressure between the two stages literally BLOWS the first (booster) stage away. This separation can be heard as a clearly audible "POP". FIGURE 26 below illustrates a typical two stage test configuration.

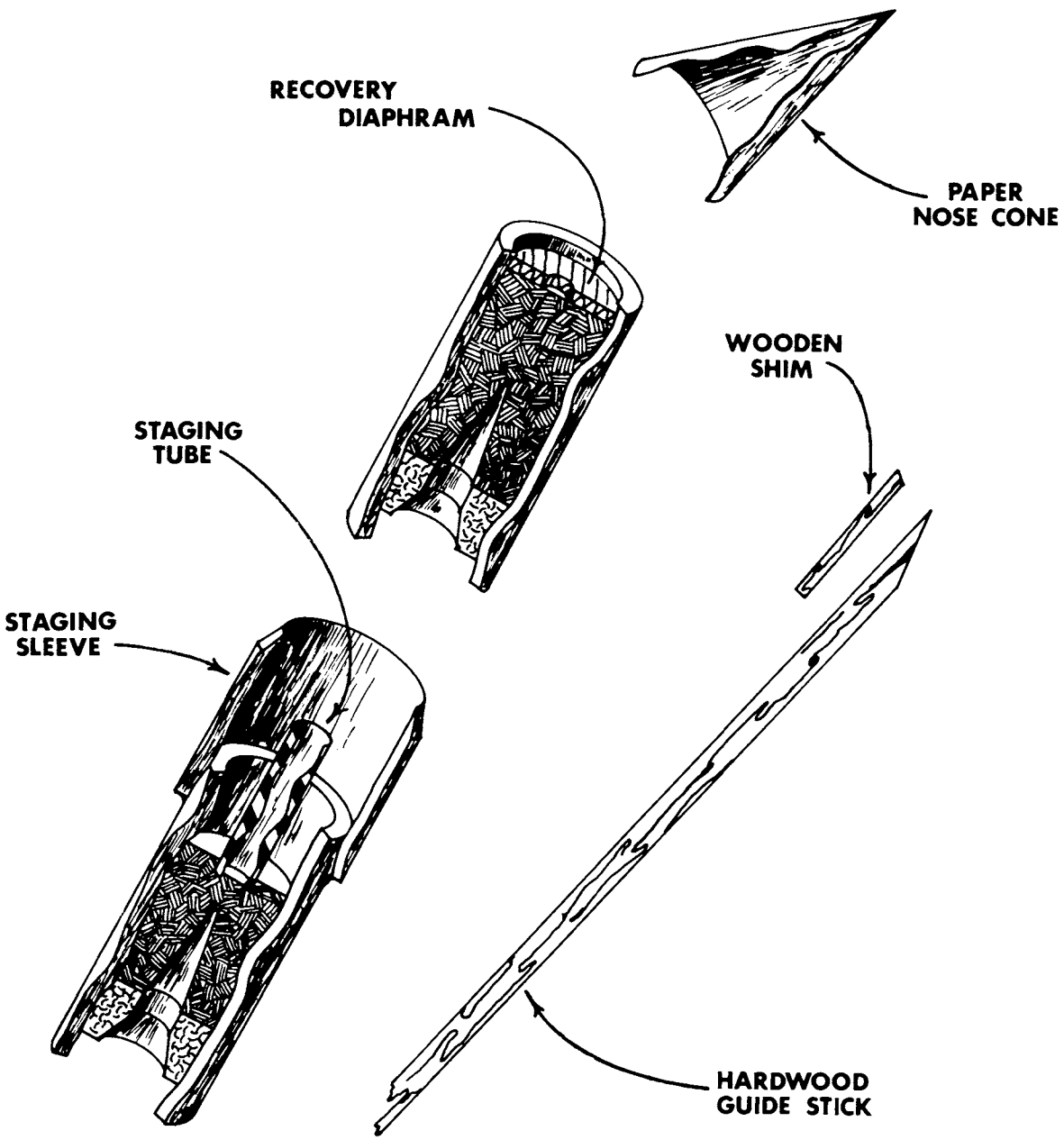
It's not a mathematically accurate representation. Rockets are long and skinny. We had to shorten and fatten everything for purposes of illustration. The drawing DOES, however, correctly represent each component in its relation to the others.

FIGURE 26



In FIGURE 27 we've disassembled it so that you can see everything more clearly. In general appearance it looks like an old fashioned Chinese rocket. You can put one together in just a few minutes, and we use this configuration for aerial testing engines that we're not quite ready to use in an expensively built model.

FIGURE 27



You can use this configuration any time that you need to AERIAL test a design that you're not certain of. An example would be as follows.

You're testing a new design for a booster, and you're not quite sure just how much powder to pack between the end of the propellant core and the staging dimple. Make up three or four different designs for testing. Couple each one to a well proven second stage engine, and tape each configuration to a simple guide stick with a paper WITCH'S HAT nose cone. Use plenty of tape around the stick; these motors are POWERFUL! File folder cardboard makes the best nose cones.

You launch rockets of this configuration from a tube. We use an eight foot length of 2 inch diameter SCHEDULE 40 PVC plastic water pipe. As you fly each configuration note when the second stage fired. Too soon? Too late? Just right? YOU decide! If you've kept accurate records and measurements of each design, then you'll be able to duplicate the one that works best. When you've got the design of the new engine down pat, THEN you can start using it in an expensively built model.

Another situation would be as follows. You're testing a single stage engine of a proven design. You've developed it to a point where it almost always pops the parachute EXACTLY at apogee.

NOW you want to use it as a SECOND STAGE motor. It will be traveling a lot faster when it runs out of fuel. It will probably coast a lot farther too! You'll have to add some extra powder to the delay charge. How much? You'll have to do some AERIAL testing.

Once again, this time, using proven boosters, fire separate configurations of each second stage engine that you wish to test. Pour a small amount of LOOSE, DRY gunpowder into the front of each second stage motor. Pack a wad of fiber glass house insulation in on top of the loose powder to hold it in place, and tape on the witch's hat nose cone.

THIS time, BEFORE you tape it onto the rocket, fill the nose cone with DRY TEMPERA PAINT POWDER. The color should be dark blue or black. You can buy DRY TEMPERA from anyone who handles art supplies. If they don't stock it they can order it for you. A one pound container will cost two or three dollars and will last A LONG TIME!

Fire the rockets from a tube as before (NEVER use a METAL tube!) When the second stage delay charge ignites the loose gunpowder in the front of the engine it will pop off the nose cone, scattering the tempera powder into a highly visible cloud in the sky. The cloud will appear exactly where the parachute would, had there been one. Once again, if you've kept accurate records you'll be able to reproduce the design that worked best, and once it's finalized, you'll be able to use it in finished models.

In FIGURE 27 the BOOSTER engine looks a little strange. What's that big thing wrapped around the front? It's a STAGING SLEEVE. It's simply another piece of cardboard tubing whose I.D. just fits over the O.D. of the booster engine. It is affixed to the booster with plain white glue.

When the two stages separate it gets blown away from the rocket along with the booster. The second stage slides smoothly into this sleeve with a telescoping fit. You can make this sleeve out of almost anything EXCEPT METAL! When testing our 3/4 inch engine designs you'll discover that the 1" I.D. engine casing works perfectly. You can sand the sleeve to a taper at its front to make it a little more aerodynamic if you like.

You make the nose cone by cutting a half a circle out of a file folder. Bend the half circle into a cone shape and stick it together with a single strip of masking tape. Make it a little bigger than necessary. Press the cone down over the front of the rocket motor (like you'd push an oversized hat down over your head), and mark the ring where it overhangs the front of the engine. Cut off any paper beyond this ring, and affix the properly sized cone to the motor front with a single wrap of masking tape.

Cut the guide stick to length. Affix it to the SECOND STAGE of the rocket with a little white glue and TWO bands of masking tape. Use PLENTY of tape. Tapering the stick helps performance GREATLY! Make it thick at the front and let it taper to half its thickness at the tail.

For the little 1/2 inch I.D. motors make the sticks 18 inches long and 1/8 inch square at the front. For the 3/4 inch engines the sticks should be 24 inches long and 3/16 inch square. Cut the one inch engine sticks 30 to 36 inches long and 1/4 inch square.

We've found that hardwoods make the best guide sticks. Softer woods like pine or fir tend to whip around in flight, hurting the rockets' performance. Remember that you can obtain all the free hardwood sticks you'll ever need by tearing apart and cutting up junked furniture. See your junk man, or just keep your eyes open while driving through the country. If you follow these guide lines in making your guide sticks, all your test flights should be straight as an arrow and smooth as silk.

Once again, look at FIGURES 26 and 27. The little "barber pole" affair sticking out of the end of the booster propellant is a STAGING TUBE. It's cut from a soda or cocktail straw. Here's how to make it, and here's what it does.

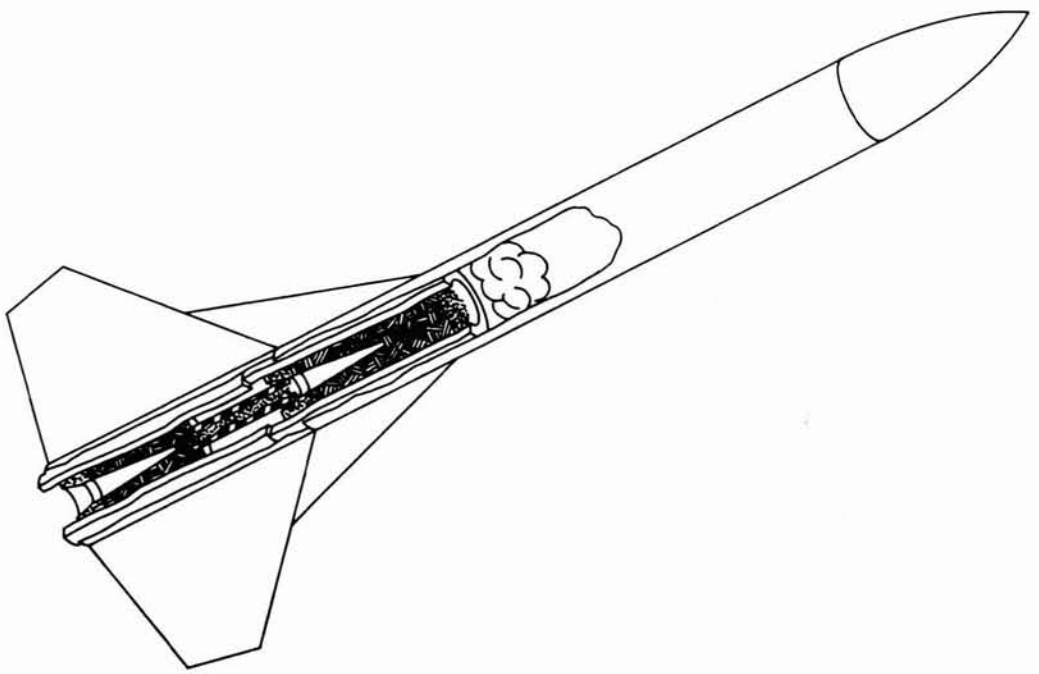
Before you slide the second stage engine into the booster's staging sleeve, cut a piece of straw to the proper length, and fit it snugly into the staging dimple in the end of the booster propellant. Common soda straws are used for the large and medium sized engines. Tiny cocktail or party straws are used for the little 1/2 inch motors.

You can buy soda straws at the supermarket. They're usually 1/4 inch in diameter, but check the size when you buy them. As stated earlier, when making the dimpling tool, make it "just a tad smaller" than the soda or cocktail straw.

The straw should be cut long enough to reach from the staging dimple in the booster propellant all the way into the propellant core of the second stage engine. Press it FIRMLY into the booster's staging dimple, and (although we don't show it in the drawings) pack fiberglass house insulation all around it. The fiberglass insulation is fireproof and will help to hold the straw in place. You can obtain enough FREE insulation scraps to last a lifetime from anyone who's building or remodeling a house.

COMPLETELY fill this soda straw staging tube with LOOSE, DRY gunpowder. You can use your homemade powder for this purpose, but in this case, WE STRONGLY RECOMMEND that you purchase a can of commercially made "FFFF FINE BLACK POWDER". The four "F's" indicate the finest, fastest burning grade. You can buy it in a sporting goods store. It is manufactured in the form of finely divided flakes that won't pack down in the staging tube during flight. It is too powerful and expensive to use as a rocket propellant, but is PERFECT for use as a staging or parachute recovery charge. After you've used it for awhile, you'll come to appreciate its merits. A one pound can currently costs about $7.00, and in the amounts that you'll need for staging and parachute deployment, that one pound can should last for several years.

BEFORE LIFTOFF



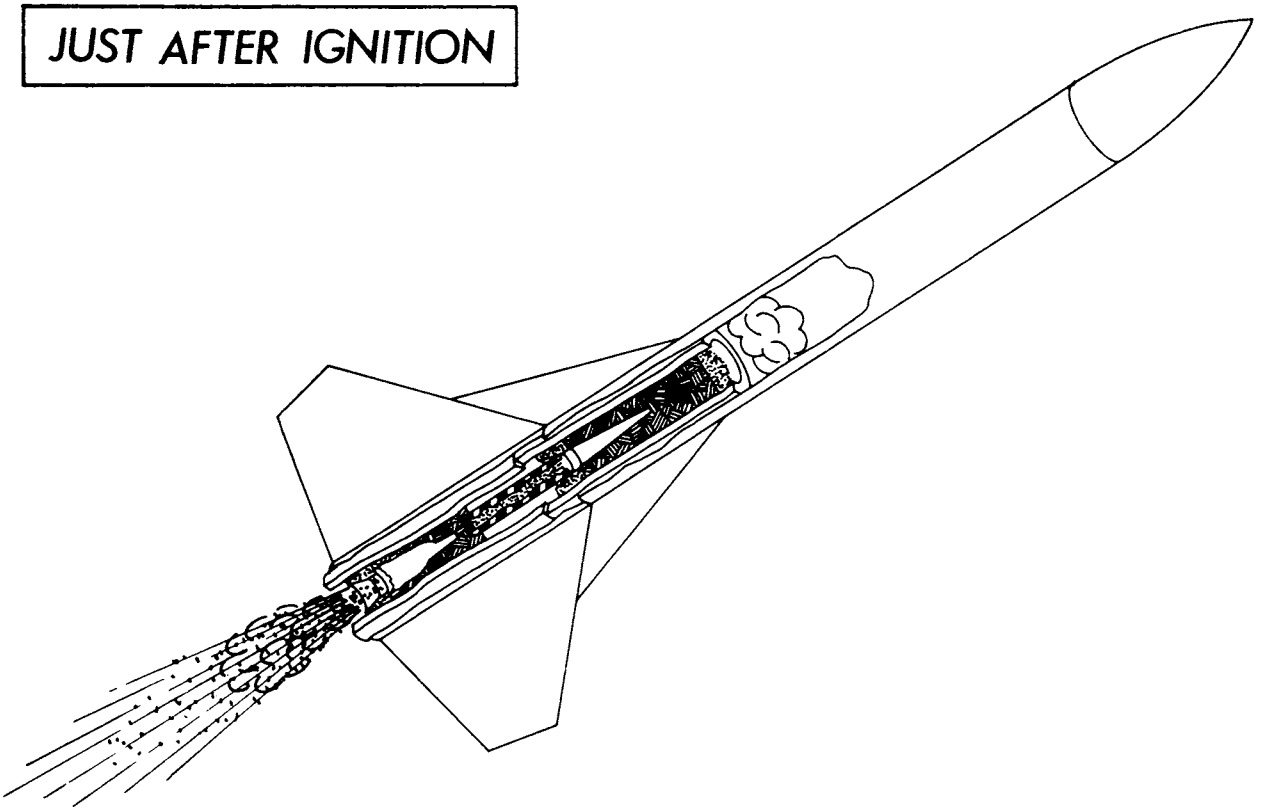
In most cases the second stage engine nozzle will be larger in diameter than the staging tube. Build up the diameter of the soda straw tube with masking tape until it fits snugly into the nozzle. Once you've connected the booster to the second stage motor, that loose gunpowder must STAY in that tube, and not be spilled out around the tube during handling.

When the booster propellant burns through and ignites this tube full of loose powder, it burns in a FLASH, igniting the propellant in the core of the second stage engine. If you wish to add a third stage to the rocket, simply use ANOTHER booster for your SECOND stage engine, and have IT ignite the third stage.

You can keep on adding stages indefinitely by this method. You're only limited by the weight of the entire assembly at lift off. We've tried out a few rockets using FOUR stages, and they're REALLY SPECTACULAR to watch!

At the bottom of the preceeding page we've drawn a cutaway picture of a typical two stage model in full dress as it might appear a moment or two before ignition. Notice the staging tube filled with loose gunpowder, and notice the puffy wad of fiberglass in front of the second stage engine. This is called the RECOVERY WADDING, and we'll explain it later. We've omitted the fiberglass that would be packed around the staging tube. It would simply get in the way of our illustrations. Just remember that it must be packed in place before the tube is filled and the two stages are united.

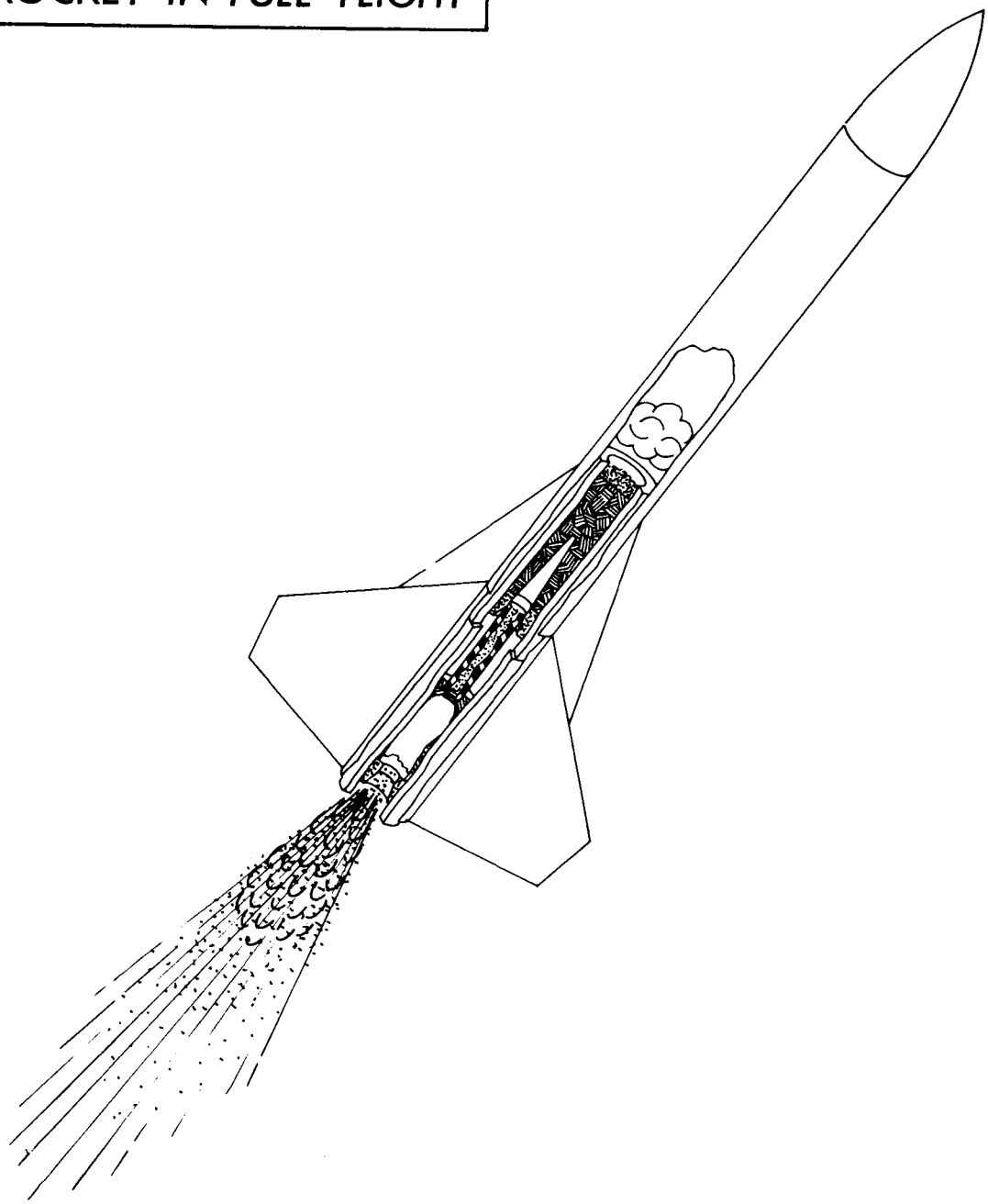
JUST AFTER IGNITION



At the bottom of page 50 we've drawn the rocket again, this time as it would appear just after ignition. You can see that the propellant is beginning to burn. The engine is building up thrust, and the rocket is lifting off the launch pad.

Just below we've illustrated the next stage of its flight. The booster engine is burning furiously now and the rocket is accelerating rapidly upward.

ROCKET IN FULL FLIGHT

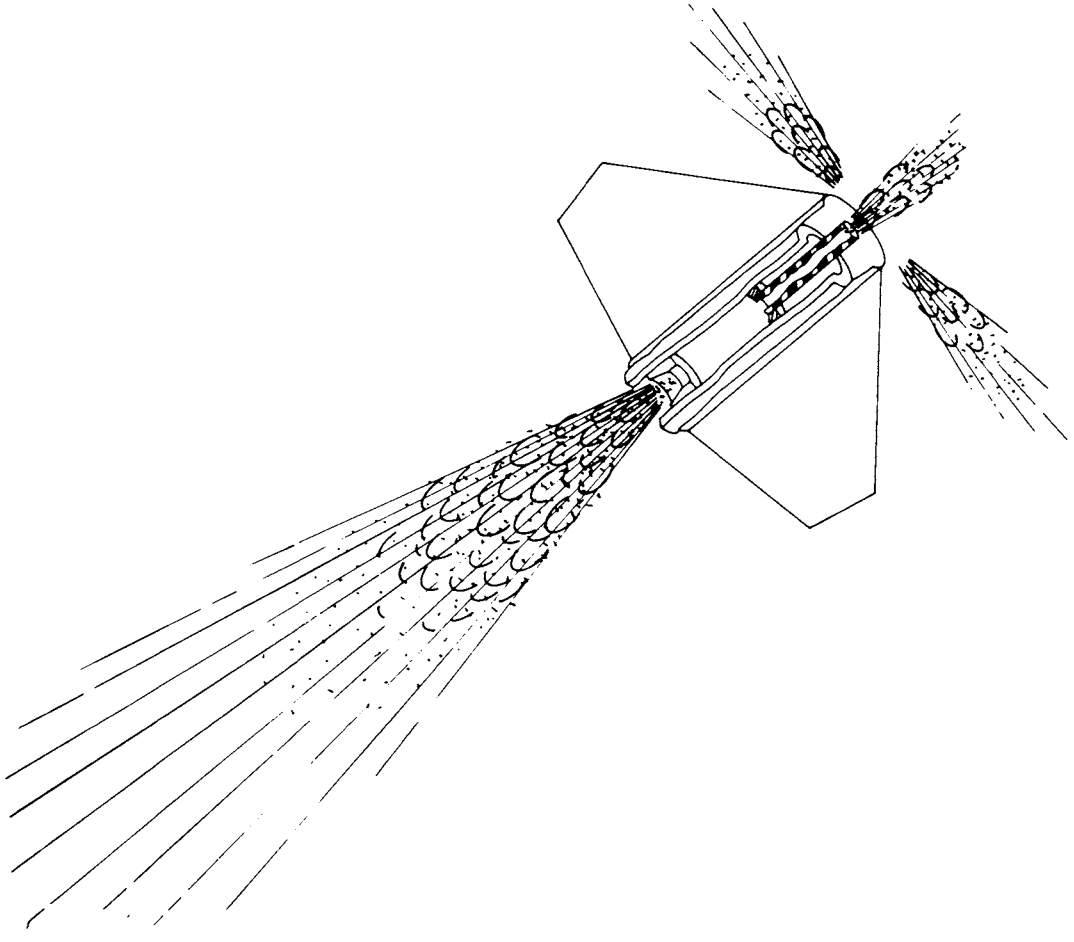


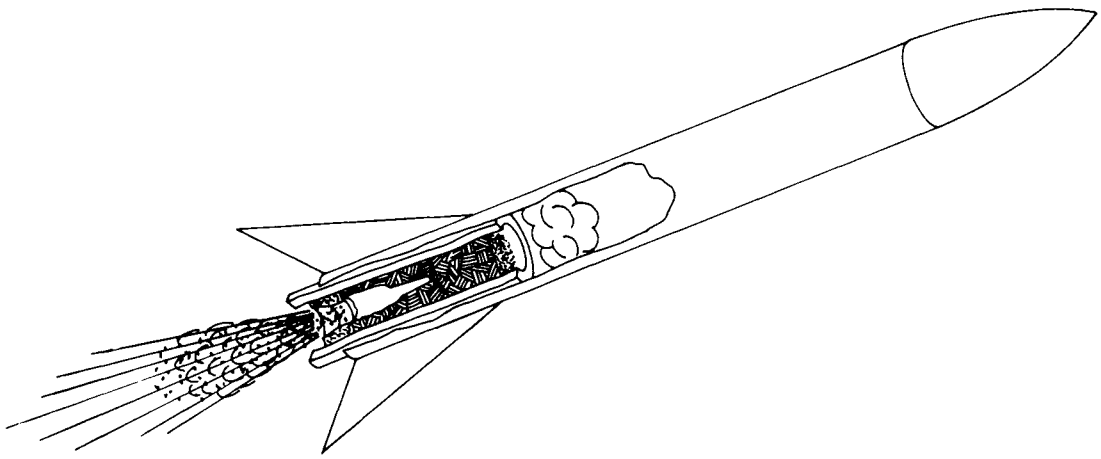
A few moments later the booster engine has consumed all its propellant and has just ignited the second stage. A puff of smoke is witnessed by the ground observers, and a moment later (it takes awhile for the sound to reach them) an audible "POP" is heard.

The entire booster assembly drops away, greatly reducing the weight of the second stage whose engine is just beginning to build thrust. It is just as though the rocket were lifting off the ground all over again, except that THIS TIME it is lighter in weight by HALF, and the launch pad is ALREADY 1000 FEET IN THE AIR and RISING UPWARD AT 300 MILES PER HOUR!

The advantages contributed by this situation are TREMENDOUS, and a properly designed two stage rocket will actually rise three or four times as high as a single stage version.

BOOSTER SEPARATION





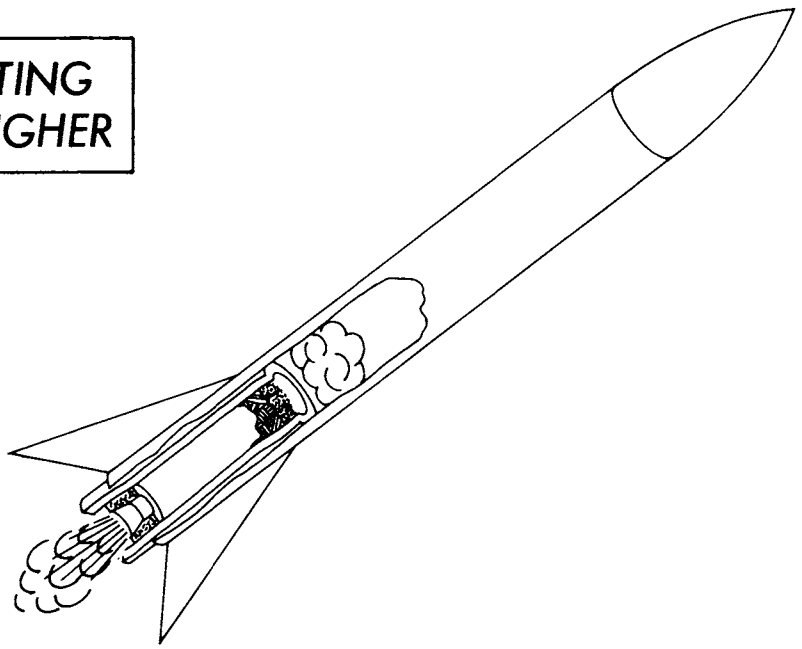
At the top of THIS page we show the second stage pulling away from the burned out booster. The rocket will enter an entirely NEW thrust cycle.

This time, instead of igniting another engine at the cessation of thrust, the missile will go into a coasting and delay phase. There is an EXTRA amount of propellant added to the engine in front of the propellant core. It will take awhile for the flame front to make its way through this unburned plug. When it DOES it will ignite a small amount of LOOSE, DRY gunpowder in front of the engine.

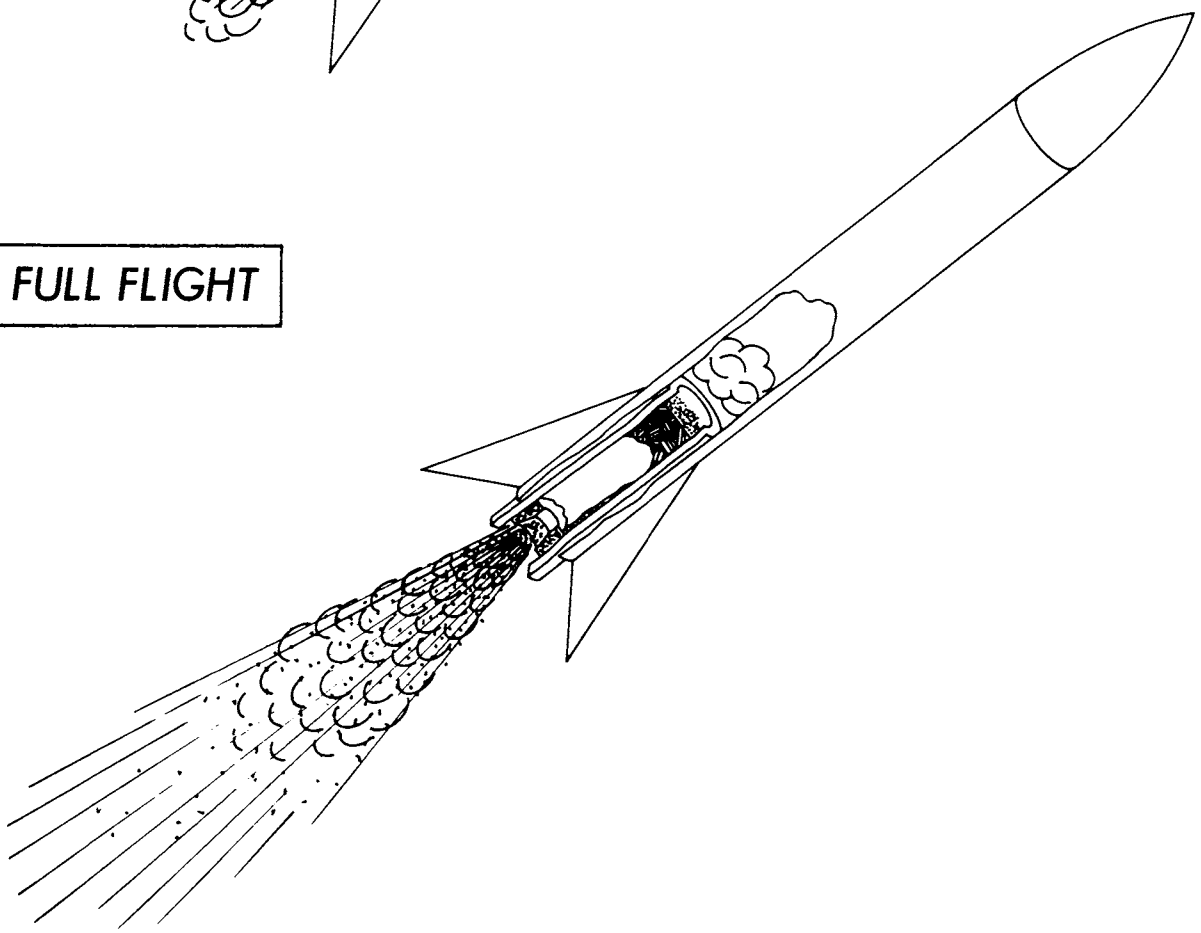
Once again we recommend commercially manufactured "FFFF FINE GRADE BLACK POWDER" for this purpose. THIS charge of powder burns with a FLASH, and produces a sudden burst of gas TOO LARGE to escape through the engine's nozzle. The only direction for the expanding gases to go is FORWARD, and in doing so they push out that bundle of fiberglass recovery wadding that we mentioned just awhile ago. When the recovery wadding is ejected it pushes the parachute and the nose cone out along with it.

If you've measured and timed everything carefully, the parachute will open EXACTLY at APOGEE. If you haven't managed to accomplish this, it's not as critical as you might think. A model rocket is actually quite light once its propellant is consumed. It will fall rapidly, but if you connect it to its parachute with a nice LONG, STRETCHY rubber band (commonly referred to as a "shock cord") that rubber band will absorb the shock when the chute opens, and you'll probably experience a safe landing.

COASTING
STILL HIGHER



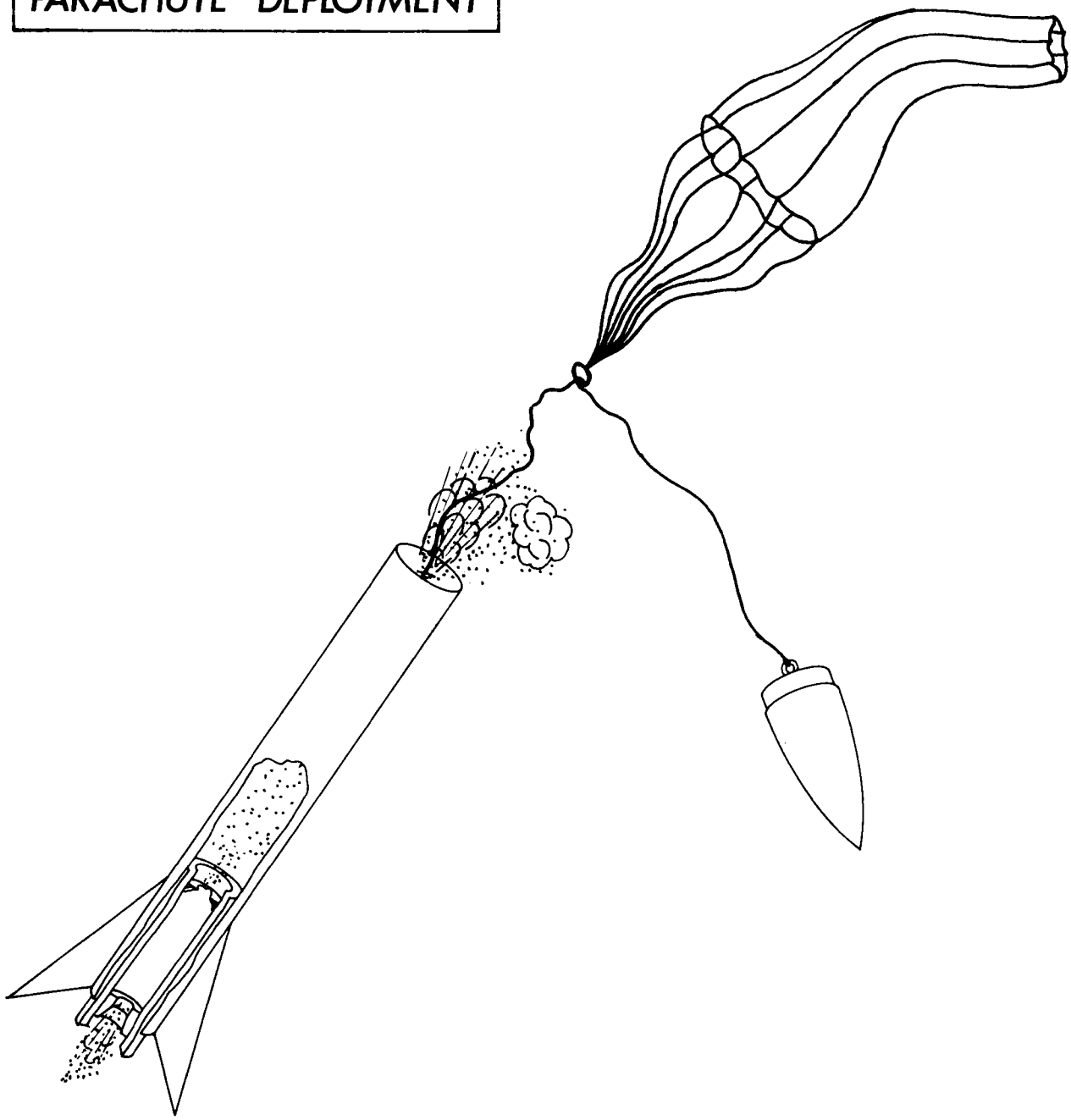
FULL FLIGHT



The lower illustration on page 54 shows the second stage in full flight and the upper illustration shows it in its coasting delay phase.

Just below (on THIS page) we've drawn the rocket at the moment of its parachute deployment. The powered phase of its flight has ended THOUSANDS OF FEET in the air, and it now floats safely homeward.

PARACHUTE DEPLOYMENT



PARACHUTE DEPLOYMENT

Before you embark on the program outlined in this manual we strongly suggest that you first purchase a commercially made model rocket kit WITH engines and that you go through the entire experience of building and launching it.

Look back at FIGURE 27 now. Look at the front of the propellant charge in the second stage motor. See that funny looking round thing? We call it a RECOVERY DIAPHRAM. It is simply a disk of dense cardboard or thin plywood with a hole punched or drilled in the center. It's glued FIRMLY to the inside wall of the engine casing just on top of the propellant charge.

A few paragraphs ago we mentioned that the parachute recovery charge produces a burst of gas TOO LARGE to escape through the nozzle. This is true ONLY if the engine has a SMALL nozzle. Two thirds of the motors described in this manual have QUITE LARGE nozzles, and these larger engines should be fitted with recovery diaphrams.

When we began experimenting with these motors we discovered that as we made the nozzles bigger, we also had to add extra amounts of gunpowder to the recovery charges to generate enough back pressure to pop the parachutes. The biggest engine nozzles are SO large that it takes almost a TABLESPOON of powder to accomplish this!

The solution to the problem is to add a recovery diaphram to the front of any engine with a large nozzle; then pour the loose gunpowder in ON TOP of the diaphram. The hole punched in the center of the diaphram is JUST big enough to allow the engine propellant to ignite the recovery charge.

Once the diaphram is in place, we can pop the parachute out with a MUCH SMALLER amount of gunpowder than would otherwise be required. The diaphram (if glued FIRMLY into the front of the engine) will limit the escape of the expanding recovery gases to the FORWARD direction.

If you place a recovery diaphram with a 1/8 inch diameter hole in its center in the front of our largest motors, then you can reduce the amount of gunpowder needed to just ONE HALF TEASPOON. This smaller amount will now effectively eject the parachute, but will not damage the model.

Assuming that you use recovery diaphrams in your larger engines, the table below will tell you a sensible amount of powder to use for each different casing size. These figures are GENERAL. They will vary a bit depending upon how large or small a model you're flying with a given engine. You can refine these figures by experimentation.

ENGINE CASING I.D.	AMOUNT OF LOOSE GUNPOWDER REQUIRED FOR RECOVERY BURST
1/2 INCH	1/16 TO 1/8 TEASPOON
3/4 INCH	1/4 TEASPOON
1 INCH	1/2 TEASPOON

In the drawings we made of the two stage rocket in flight we showed a tuft of fiberglass recovery wadding stuffed into the rocket body tube between the second stage engine and the parachute. Before loading the engine into the model you must ALSO pack fiberglass wadding into the front of the motor ON TOP of the loose gunpowder recovery charge. This additional packing holds the powder in place during handling and flight.

IGNITER PLACEMENT IS CRITICAL!

For a core burning engine of established design, the performance can vary GREATLY depending upon how deeply you insert the igniter into the propellant core. These motors are designed for OPTIMUM performance.

In all of the smaller rocket motors UP TO and INCLUDING the 3/4 inch I.D. D-18, insert the paper match electric igniter into the propellant core AS FAR AS IT WILL GO.

IN ALL LARGER MOTORS NEVER insert an igniter deeper than HALF the length of the propellant core! For example, if an engine has a FOUR INCH deep core hole, NEVER insert an igniter DEEPER than TWO INCHES into that hole! If you disobey this rule, the motors with the DEEPEST cores will probably explode on the launch pad.

To eliminate the possibility of an error, simply make the leads on the electric igniter short enough that the igniter simply CAN'T be inserted too deeply. When launching ALL of the motors make sure that the igniter ACTUALLY TOUCHES the gunpowder surface inside the propellant core.

Run the electric igniter leads out through the engine nozzle and tape them in place with a single strip of masking tape. Engine ignition will INSTANTLY INCINERATE the tape. The rocket will lift off, leaving the burned out igniter still clipped to the electrical power leads on the launch pad.

NEVER USE A "FUSE" or ANY manual means of lighting a model rocket engine! Use ONLY an ELECTRIC IGNITER operated REMOTELY from a SAFE DISTANCE! We offer plans for an electric igniter that you can make from materials you'll find around the house. If you didn't receive the plans along with the brochure we sent you, send us $2.00, and we'll mail you the plans along with a WORKING SAMPLE.

Be SURE that you observe all local, State, and Federal fire and safety codes. ALWAYS stand at least 25 feet from the launch pad when firing your engines, and when launching anything larger than an "E", stand AT LEAST 50 FEET AWAY!

IN CONCLUSION

All of this can sound a little difficult if you've never tried it. If you feel a little inadequate at the beginning we suggest the following.

Start with the little A-3 motor. Although it's our tiniest, it lifts off with an impressive WHOOSH! It uses only 3/8 of an ounce of propellant, so you can build a dozen motors with 1/4 pound of powder. It will carry a featherweight model to 1000 feet, and it can be flown in an area the size of a football field.

If you've obtained a copy of the 3/4 INCH CASING SUPPLEMENT we recommend that you start with the D-18. It is very compact and uses only an ounce of propellant. It is VERY POWERFUL for its size and will AMAZE you with its performance.

As stated before, use caution in everything you do. Before you launch a rocket be sure to follow the proper legal procedures, and be sure to consider the safety of everyone around you AND their property. Building your own rocket motors IS an exciting and educational experience. Enjoy yourself, but most of all:

BE SAFE!

TROUBLE SHOOTING

To recap some of the things that we've talked about, we're providing you with a trouble shooting chart. We hope that it will aid you in becoming proficient at the required tasks.

PROBLEM	POSSIBLE CAUSE	SOLUTION
Potassium nitrate forms giant concentrations in the powder mill.	The nitrate is NOT dry.	Discard the concretions and start over with DRY potassium nitrate.
Nozzle crumbles away when ramrod is removed from casing.	Ceramic powder was not rammed hard enough into the engine casing.	Replace the ramrod. Add enough fresh powder to make up for the loss. Then ram it in HARDER.
Ramrod is jammed into nozzle so tight that you can't remove it.	You hammered it in harder than necessary OR	Remove it by whatever means works, and go easier with the hammer next time.
	You forgot to lubricate the ramrod before using it.	Remember to coat the ramrod with Non Stick Vegetable Cookware Coating for your next engine.
Kraft paper engine casing is split when removed from the casing retainer.	Casing retainer was TOO LOOSE.	Discard the defective engine. Be sure the clamps are TIGHT next time.

PROBLEM	POSSIBLE CAUSE	SOLUTION
Finished rocket engine shows wrinkles in the casing and propellant cracks when removed from the casing retainer.	Casing retainer was TOO LOOSE.	Discard defective engine by soaking in water. Make a new engine, and be sure clamps are TIGHT next time.
	OR	
	All ingredients were rammed TOO TIGHTLY into the casing.	Discard the defective engine. Make a new one, and go easier with the hammer next time.
Rocket propellant lacks power.	You reduced the sulfur too much.	Increase the sulfur content of your next batch.
	OR	
	You didn't measure the ingredients properly.	Discard the substandard propellant, and start with fresh ingredients. Weigh everything CAREFULLY this time (or obtain some more accurate weighing equipment).
Finished rocket lacks power.	Propellant is not thoroughly DRY.	Make sure your engines are completely CURED (dry) before launching.
	OR	
	Propellant core was too short.	Check your measurements and if necessary lengthen it next time.
Rocket burns unevenly. It makes a "sputtering" sound during flight.	You packed the propellant unevenly.	Use a greater number of SMALLER doses when loading and tamping. Tamp FIRMLY next time.
	OR	
	You didn't distribute the water EVENLY through the powder before loading.	Follow instructions in the book concerning the distribution of water throughout the propellant. Mix EVENLY next time.

PROBLEM	POSSIBLE CAUSE	SOLUTION
Rocket EXPLODES on the launch pad.	Propellant core was TOO DEEP.	Make appropriate corrections in the next engine.
	OR	
	Propellant was TOO DRY when you tamped it into the casing.	Make appropriate corrections. Make SURE you have the proper moisture content. DON'T let the powder dry out while you're tamping it! Keep bowl covered when not in use.
	OR	
	You misplaced the igniter.	Follow instructions on igniter placement. Move igniter closer to nozzle throat next time.
	OR	
	Propellant charge was CRACKED.	Make appropriate corrections in making and handling your next engine.
	OR	
	Propellant sulfur content was TOO HIGH.	Reduce the sulfur content in your next propellant batch.
	OR	
	Propellant was milled TOO LONG.	
Second stage engine ignites TOO SOON.	Not enough distance between propellant core and staging dimple.	Make appropriate corrections.
Second stage engine ignites TOO LATE.	TOO MUCH distance between propellant core and staging dimple.	Make appropriate corrections.
Parachute ejects TOO SOON.	Not enough delay charge in front of propellant core.	Add powder to the front of the next engine.

PROBLEM	POSSIBLE CAUSE	SOLUTION
Parachute ejects TOO LATE.	TOO LONG a delay charge in front of the propellant core.	Reduce length of delay charge in your next engine.
Parachute fails to open.	Not enough loose powder for recovery burst.	Add more powder next time.
Model explodes or burns upon parachute ejection.	TOO MUCH loose gunpowder for recovery burst.	Use less next time.
Launch pad ignition failure.	Defective igniter.	Replace igniter.
	OR	
	Igniter not touching powder.	Replace with a new igniter and make sure it touches the powder next time.
	OR	
	No power to the igniter.	Check battery and all electrical connections. Correct problem and try again.
Repeated failure to ignite although everything seems O.K.	Dirty propellant core. We traced our problem to an oily film of Non Stick Vegetable Cookware Coating on the inside of the propellant core. We had used TOO MUCH of the coating on the ramrod. When we inserted the coring pintle it coated the pintle and was transferred from there to the propellant core.	Discard defective engine and GO EASIER with the coating on the next one.

APPENDIX A

MOISTURE CONTROL

MOISTURE IN THE ENGINE CASINGS

To begin with, it is imperative that your engine casings be made from HEAVY WALLED KRAFT PAPER. This entire engine building system relies on the fact that paper expands when it is wet and contracts again when it dries out. Other materials such as the commonly availabe types of plastic water pipe will simply NOT work, and should you attempt to use them in conjunction with the techniques described in this book, your motors will fail every time.

Additionally, the casings must be made of a special type of tubing uniquely suited to rocket motor construction. There are two types of paper tubing commonly available to the public market. The one you are most familiar with is the SPIRAL WOUND variety. Mailing tubes and the cores of paper towel rolls are made from spiral wound tubing.

YOU CANNOT USE SPIRAL WOUND TUBING IN THE CONSTRUCTION OF ROCKET ENGINES.

Each layer of paper in a spiral wound tube contains a tiny spiral air channel. If you build a rocket motor using such tubing, the heat of engine ignition will first burn through the first thin layer of paper on the inside of the motor casing, exposing the first spiral air channel. The high pressures generated during engine operation will then force hot combustion gases up this channel, prematurely igniting the rest of the propellant mass and causing the motor to explode.

CONVOLUTE WOUND tubing, on the other hand, is SOLID throughout its entire thickness. It is made by rolling a sheet of paper of specified width and thickness onto a round mandrel, like a jelly roll or a window shade. The paper is first soaked in water and coated with glue. When the madrel is withdrawn, the finished tube is stacked up with others and dried.

Tubes made in this manner will erode slightly on their inside surfaces during engine operation, but there will be no place for the hot conbustion gases to escape, except out the engine nozzle, and it is for this reason that black powder rocket motors are built EXCLUSIVELY with CONVOLUTE WOUND KRAFT PAPER TUBING.

In order for a black powder rocket motor to work properly, the hardened and cured propellant charge must be FIRMLY BONDED to the inside of the motor casing.

During operation, internal engine pressures will reach hundreds of pounds per square inch, and if the unburned propellant plug in the front of the motor is loose, it will be blown out the front of the engine like a cork out of a pop gun.

On page 34 in the book we told you to dampen the gunpowder before tamping it. When this dampened and compressed powder dries, it shrinks, and if you were to pack it into a "bone dry" engine casing, it would actually shrink away from the walls of the casing during the curing process.

Just like the gunpowder, you need to dampen your engine casings before you use them. If they are moist to start out with, then they will shrink right along with the gunpowder as it dries, and the end results will be a good, tight fit.

When you receive your engine casings, they will contain whatever moisture they happened to pick up out of the air in the most recent environment. Under normal, "comfortable" weather conditions they will hold 9% or 10% of their total weight in free water. Under extremely dry conditions this percentage may drop to 7% or 8%, and during the rainiest weather it may rise to 11% or 12%.

In order to achieve the most desirable, tightest fit in the cured rocket motor, you need to start with the dampest engine casing that you can practically use, and through trial and error, we've discovered this figure to be 15% to 17% moisture content. This amount of water works well for the breed of tubing that we use and sell, you would probably be satisfactory for just about any paper tubing that you might find.

You can make a very simple apparatus to raise the moisture content of these tubes, and we've sketched it on the next page. Place an empty 46 ounce "grapefruit juice" can in the bottom of a clean, thirty gallon plastic household trash container with a tight fitting lid. Place dry rags all around the can, and fill the can about 2/3 full of water.

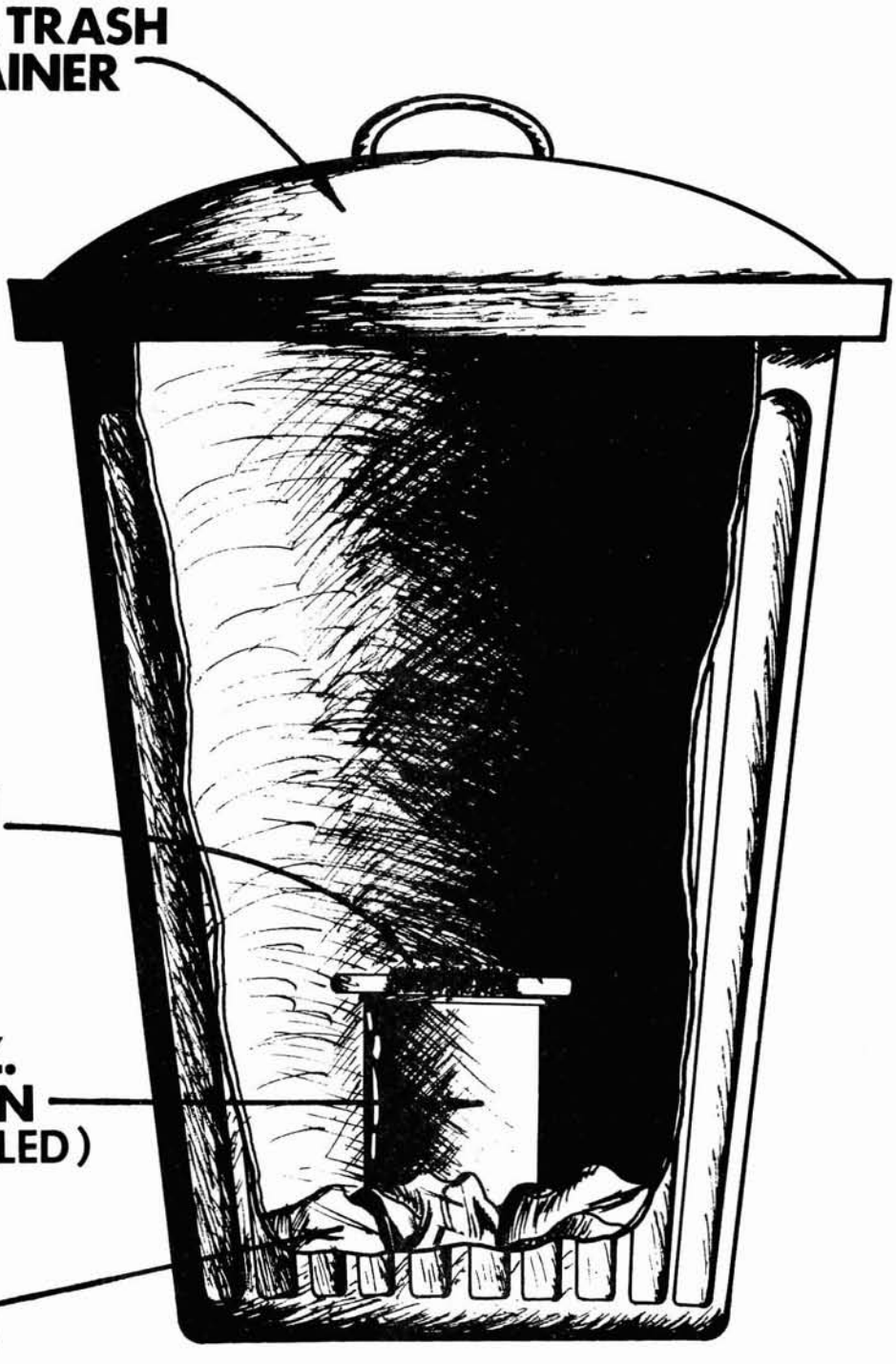
Next place a pencil or a small stick across the top of the can, and drape a piece of terry cloth or corduroy over the stick and down into the water. This "wick" should be about 2 inches wide and long enough for each end to reach down into the water.

Pile dry rags all around the water-filled can, and stand your engine casings on end on the dry rags. Soak a large bath towel with water and wring it out. Fold the dampened towel in half and stretch it across the top of the trash container. Now press the lid of the container down over the bath towel, and allow the entire sealed apparatus to sit INDOORS at room temperature for about 24 hours.

After 24 hours have passed, remove the bath towel and replace the plastic lid of the container. At this point the wick in the water-filled can will provide enough moisture to the air in the container to keep the dampening process going, and after 4 or 5 days, the tubes will be ready to use.

They will absorb 15% to 17% of their weight in moisture from the air in this sealed environment, and when you remove them, they will feel slightly damp. They will feel firm, but pliable enough, that if you squeeze either the 3/4" or the 1" casings firmly between your thumb and forefinger, you will be able to slightly crush the ends. If they get TOO MUSHY, (around 18% or 19%) they won't stand up to the forces of loading and tamping.

CASING HUMIDIFIER



We've found that these paper engine casings can sit in this apparatus for one or two months without developing any significant amount of "mildew", and once every two or three months, we remove the rags, wash them, and replace the water in the can, starting the entire process over again with a freshly dampened bath towel over the top.

If you wish to actually determine the exact moisture content of a load of casings, you can do it by weighing a sample. Remove one of the tubes from the moisturizer, and cut off a short length for study. Weigh this piece of engine casing. Then bake it in the kitchen oven at 275 degrees Fahrenheit for an hour or two. Weigh it again.

Baking the casing drives off ALL the free moisture, and the difference in weight before and after baking divided by the total weight before baking will give you the percentage moisture content.

An example would be as follows:

WEIGHT BEFORE BAKING: 15.40 Gms.
WEIGHT AFTER BAKING: 13.17 Gms.

$$\frac{15.40 - 13.17}{15.40} = .1448\ (14.5\%)$$

14-1/2% is a little on the dry side, so you would, in this case, decide to let the tubes "soak" for a little longer, or perhaps you would replace the dampened bath towel for another 12 hours or so.

Once you've gained some experience at this you should develop a "feel" for how moist the casings should be, and you'll probably be able to dispense with a lot of the "riggamarole" involved in the beginning.

OUR experience, although it's a bit difficult to put into words, has been as follows. These descriptions apply to the 3/4" and 1" I.D.tubes that we use and sell. If the casings feel "hard as a rock", almost brittle, they are VERY DRY (around 4% or 5%). If they're not actually brittle, but feel "tough" and "stiff", they are probably around 9% or 10% moisture content.

At about 16% they are more pliable, and you can, as we said before, slightly crush the ends by squeezing firmly between the thumb and forefinger. At 18% they will become EXTREMELY pliable, and would probably not stand up to loading and tamping procedures, and at anything over 20% or 21% moisture content they will feel "downright mushy".

Gaining control of the moisturizing process is EXTREMELY IMPORTANT to the quality of your finished engines, and we STRONGLY URGE that you not rush the process. Once you've established, and become familiar with a workable system, you'll be able to keep a continuous supply of properly moistened tubes on hand with virtually no effort at all.

MOISTURE IN THE PROPELLANT

Equally important is the moisture content of your gunpowder, both during loading, and in the cured and finished motors. If you let your ingredients, and/or your finished propellant sit around uncovered, they will absorb moisture from the air, and this will cause serious problems when you attempt to dampen your powder before tamping.

If, instead, you start out with bone dry ingredients, you'll always know where you stand as far as moisture is concerned. Put several pounds of the nitrate beads or crystals (whichever you are using) in a large, uncovered pot, and bake the material at 300 degrees Fahrenheit in the kitchen oven for several hours. The charcoal may be treated in the same way, although the temperature should be lowered to about 250 (If you allow the charcoal to get too hot, it will actually ignite and start to burn very slowly just like it does in a Bar-B-Que). Don't bother attempting to dry out the sulfur. It melts at a little over 200 degrees F., and it will really smell up your kitchen. Since it is used in such small quantities in your gunpowder, what little moisture it DOES contain will pose no problem.

Once the ingredients are dry, KEEP THEM DRY! Store them in tightly sealed containers, and make your gunpowder using ONLY these dry materials. Keep your finished propellant dry also. Keep it in a tight container until just before you're ready to use it. THEN add 8 teaspoons of water per pound, and you'll be on your way to success.

YOU MUST HAVE THE CORRECT AMOUNT OF MOISTURE IN THE POWDER FOR LOADING AND TAMPING! Eight teaspoons of water per pound give the gunpowder an 8-1/2% moisture content. This amount of water works very well for all operations described in this manual, and it's an easy number to divide up or multiply for smaller or larger batches.

If you add MORE water than this, you will experience bloating and swelling of the propellant charge immediately after tamping. If you look down into the engine casing, you will see the finished surface of the gunpowder that you just tamped beginning to bloat and swell into a dome shape, and this is a sure sign that your powder is too wet. If you notice this phenomenon occuring in one of our rocket motors, THERE IS NO WAY TO REPAIR IT. The motor is USELESS and DANGEROUS and must be discarded.

If you add LESS water than the proper amount, the tamped pellet of propellant will not bond properly to the inside of the dampened casing. Additionally, using less than the correct amount of water will allow the cured propellant charge to become POROUS. This porosity will allow the flame to travel too fast during ignition, and your engines will explode. If you stay with 8 teaspoons of water per pound of dry gunpowder, you should easily achieve consistent success.

MOISTURE IN THE FINISHED ENGINES

Once you've established the design of a particular rocket engine, you'll find that raising or lowering the moisture content of the finished motor will correspondingly raise and lower the chamber pressure and thrust.

This factor can make a tremendous difference in how well your rockets fly, and a motor that barely lifts off the ground when it's first made (8-1/2% propellant moisture) will fly beautifully when the propellant moisture is reduced to 2% or less.

To CURE something does NOT mean to render it "bone dry". When you "cure" one of these rocket engines, you bring its moisture content back down to a relatively stable level, where, hopefully, it will remain indefinitely.

Under "normal, comfortable" weather conditions the casings will hold 9% or 10% moisture by weight, and the gunpowder will hold around 1-1/2%. When you make one of these motors, you give the casing a 16% moisture content, and you give 8-1/2% to the gunpowder. If you know the weight of the casing when you began loading and the weight of the dampened gunpowder that you loaded, then you can calculate how much moisture must be lost in order to bring the finished engine down to these desired levels.

FOR EXAMPLE:

THE DAMPENED CASING WEIGHS: 54.9 GRAMS @ 16% MOISTURE CONTENT.

THE DAMPENED GUNPOWDER WEIGHS: 127.4 GRAMS @ 8-1/2% MOISTURE CONTENT.

In order to bring the 16% engine casing down to 9%, it must lose 7% of its total weight.

IT MUST LOSE: .070 X 54.9 = 3.84 GRAMS

In order to bring the 8-1/2% gunpowder down to 1-1/2%, it must also lose 7% of its total weight.

IT MUST LOSE: .070 X 127.4 = 8.92 GRAMS

ADDING THE TWO FOR A TOTAL:

8.92 GRAMS

+3.84 GRAMS

12.76 GRAMS

12.76 GRAMS IS THE TOTAL DESIRED ENGINE WEIGHT LOSS.

Notice how the figure "7%" keeps appearing in the calculations. If you've made the engines according to our instructions, then a 7% weight loss turns out to be just about right for both the casings AND the propellant.
This simplifies thing greatly in the following way. Weigh each motor immediately after you've made it. Subtract 7% of that weight (or simply multiply by 0.93), and write the resultant figure on the engine casing. This figure represents that particular motor's proper firing weight.

FOR EXAMPLE:

IF THE TOTAL MOTOR WEIGHT BEFORE DRYING WERE 100 GRAMS

93 X 100 GRAMS = 93 GRAMS

93 GRAMS WOULD THEN BE THE MOTOR's PROPER FIRING WEIGHT.

If you live in a hot and dry climate, you can probably air dry your motors quite effectively. The smallest will take about a week, and the largest about three weeks. If you live in a wet and rainy part of the world, it is unlikely that you'll be able to achieve the proper moisure content by this method, but don't despair. There are a couple of ways to get around the problem.

The first is to increase the sulfur content of the gunpowder, and we'll talk about that in the next appendix. The second and more desirable solution is to ARTIFICIALLY dry the motors, and you can accomplish this in a home food dehydrator. Ours cost $120, but since we originally purchased it we've seen smaller, but perfectly adequate versions in the local discount stores for as little as $40.

One thing that we wish to stress here is that YOU SHOULD NOT PURCHASE A CHEAP VERSION OF A DEHYDRATOR THAT WORKS WITH A LIGHT BULB OR AN EXPOSED HEATING ELEMENT. The dehydrator MUST have a fan that blows the warm air continuously across the damp motors. This fan prevents heat from building to a dangerous point in any one area. The dehydrator SHOULD have a heating element mounted behind a set of baffles, so that, should a spark ever be released as a result of an electrical short, the likelihood of it reaching the rocket motors will be minimized.

NEVER OPERATE YOUR DEHYDRATOR INDOORS. ALWAYS PLACE IT IN A PROPERLY SANDBAGGED CONTAINMENT, so that if the engines are ever accidentally ignited, the fire will be effectively contained. Remember that the sandbag containment must be strong enough to withstand the onslaught of a dozen or more wild rocket motors, and in this case particularly, it seems that placing a 50 gallon wading pool full of water on the roof would be an especially good idea.

In the main text of the book we stated a figure of 105 degrees Fahrenheit to be used in artificial drying. Actually, this is an average. If the weather is very wet and rainy, you might want to turn the temperature up to 115 degrees. If the weather is very dry, turn it down to 95 or 100.

Weigh each motor periodically, and when you've gotten it down to its approximate firing weight, remove it from the dehydrator and seal it in a ziplock plastic bag along with a few others. The little 1/2 inch engines will probably be ready overnight. The 3/4" motors will take 18 to 20 hours, and the big 1 inch and 1-1/8" engines will require 36 to 48 hours to reach the proper weight.

NEVER STORE MORE THAN 2 OR 3 MOTORS IN ONE BAG, AND NEVER STORE A LARGE NUMBER OF MOTORS IN ANY ONE PLACE.

FIGURE 28 below illustrates what happens when you artificially dry an engine. Each illustration is a cross sectional view of a core burning motor taken as though the engine in question had been sliced "like a carrot".

(A) illustrates the motor just after you've finished making it. (B) shows it just after you've removed it from the dehydrator, and (C) illustrates the engine when it has reached its ideal firing condition. All the little "m's" represent moisture.

FIGURE 28

Artificial drying proceeds rapidly enough that it severely dehydrates the surface areas of the motor, yet leaves quite a bit of residual moisture in the deeper portions of the propellant charge (See FIGURE 28, Illustration B). Although the net weight loss for the engine is correct, it will, if fired in this condition, generate only 50% to 60% of its intended thrust.

If these engines are to be really great performers, they must be allowed to "sit around" for awhile to allow the moisture to redistribute itself in an even manner. (C) illustrates this final ideal condition. Note that the net moisture content is the same as in illustration (B) (the total number of "m's" is the same), but that the excess that existed previously in the deeper portions of the propellant has now migrated into the casing and the immediate surface of the propellant core.

The result of this process is that the propellant overall gains GREATLY in power, and a motor that developes 6 pounds of thrust when removed from the dehydrator will generate 12 pounds of thrust once this process has been allowed to proceed to completion.

The smallest motors should sit for a week. The 3/4" engines will take about 10 days, and the bigger models should be ready to fire in about 2 weeks. The process can be speeded up, and the waiting time cut in half, if you place the sealed bags of engines back into the dehydrator and leave the temperature at about 115 degrees Fahrenheit.

WARNING!

NEVER ATTEMPT TO DRY ROCKET ENGINES OR PROPELLANTS IN A KITCHEN OVEN OR ANY APPLIANCE DESIGNED FOR COOKING.

NEVER PLACE GUNPOWDER OR FINISHED MOTORS IN A MICROWAVE OVEN. THE MICROWAVES WILL CAUSE THE POWDER TO EXPLODE!

MOTORS THAT YOU CAN FIRE IMMEDIATELY (NO WAITING):

If you live in a wet climate, DON'T plan on purchasing a food dehydrator, and DON'T want to wait a week before firing your first rocket, TRY THE FOLLOWING PROCEDURE.

1. START WITH AN UNMOISTURIZED ENGINE CASING (I.E. JUST AS YOU RECEIVED IT IN THE MAIL).
2. INCREASE THE DEPTH OF THE PROPELLANT CORE BY 50% (I.E. 3 INCHES INSTEAD OF 2 INCHES).
3. PREPARE A BATCH OF GUNPOWDER CONTAINING A FULL 10% SULFUR.
4. FOLLOW ALL INSTRUCTIONS FOR NORMAL ENGINE CONSTRUCTION.
5. TEST FIRE THE ENGINE IMMEDIATELY UPON COMPLETION.

If the motor performs poorly, make a longer coring pintle and a deeper propellant core in the next engine. If it explodes on the test stand, shorten the pintle accordingly. With an afternoon or so of practice and experiment, you should be able to arrive at an engine design that you can build and test on the spot immediately, and you should, thereby, be able to pack several dozen experiments into just one weekend. This situation will allow you to practice extensively with many of the aspects of engine construction in a relatively short span of time and help you become expert in the tasks involved in the construction of a high quality rocket motor.

APPENDIX B

SULFUR CONTENT

Small variations in the sulfur content of the propellant can GREATLY effect the performance of your engines. If you've gained control of the moisturizing and curing processes described in Appendix A, and your motors seem to fly poorly, then RAISE the sulfur content by 1/2%. If everything else remains consistent, you should notice a DISTINCT improvement. If you're still not satisfied, go up a little more. If your engines begin exploding on the test stand, then LOWER the sulfur content to a safer level.

OUR BEST FLIGHTS HAVE BEEN MADE WITH ENGINES BUILT ACCORDING TO THE INSTRUCTIONS IN THE MAIN TEXT USING A PROPELLANT WITH A 3% SULFUR CONTENT, AND A STORAGE TIME OF 10 DAYS OR MORE AFTER REMOVAL FROM THE DEHYDRATOR.

Motors built with a propellant containing a 2-1/2% to 3-1/2% sulfur content can be stored indefinitely without fear that the power of the propellant will ever exceed the bursting strength of the kraft paper engine casings.

If you plan to use the motors immediately upon removal from the dehydrator, then you will wish to experiment with higher levels of sulfur.

BE WARNED, HOWEVER, THAT IF YOU MAKE AN ENGINE WITH AN ELEVATED SULFUR CONTENT, IT MUST BE FIRED EITHER IMMEDIATELY OR SOON AFTER COMPLETION, OR IT WILL BECOME DANGEROUS AND HAVE TO BE DISCARDED.

You may wish to experiment with the following propellant recipe:

POTASSIUM NITRATE 70%
CHARCOAL.....30%

It has NO SULFUR at all, but is just about as powerful as the 3% mixture that we recommend in our engine plans. It is cleaner burning than our standard mixtures, but it DOES have a drawback. Since it employs an elevated CHARCOAL content and a reduced NITRATE content, it tends to be rather structurally weak, and is quite easily cracked or broken in its compressed and fully cured form. Recrystalized potassium nitrate is the "glue" that holds the finished propellent charge together, and there must be enough of it to render the structure dense and sound. Table 1 on page 11 will provide you with TWENTY ONE black powder recipes varying in sulfur content from NO sulfur to a full 10% sulfur.

TABLE 1

NO SULFUR	1/2% SULFUR	1% SULFUR
NITRATE: 416.7 GRAMS	NITRATE: 414.6 GRAMS	NITRATE: 412.5 GRAMS
CHARCOAL: 83.3 GRAMS	CHARCOAL: 82.9 GRAMS	CHARCOAL: 82.5 GRAMS
	SULFUR: 2.5 GRAMS	SULFUR: 5 GRAMS
1-1/2 % SULFUR	**2% SULFUR**	**2-1/2% SULFUR**
NITRATE: 410.4 GRAMS	NITRATE: 408.3 GRAMS	NITRATE: 406.2 GRAMS
CHARCOAL: 82.1 GRAMS	CHARCOAL: 81.7 GRAMS	CHARCOAL: 81.3 GRAMS
SULFUR: 7.5 GRAMS	SULFUR: 10 GRAMS	SULFUR: 12.5 GRAMS
3 % SULFUR	**3-1/2% SULFUR**	**4% SULFUR**
NITRATE: 404.2 GRAMS	NITRATE: 402.1 GRAMS	NITRATE: 400.0 GRAMS
CHARCOAL: 80.8 GRAMS	CHARCOAL: 80.4 GRAMS	CHARCOAL: 80.0 GRAMS
SULFUR: 15 GRAMS	SULFUR: 17.5 GRAMS	SULFUR: 20 GRAMS
4-1/2 % SULFUR	**5% SULFUR**	**5-1/2% SULFUR**
NITRATE: 397.9 GRAMS	NITRATE: 395.8 GRAMS	NITRATE: 393.7 GRAMS
CHARCOAL: 79.6 GRAMS	CHARCOAL: 79.2 GRAMS	CHARCOAL: 78.8 GRAMS
SULFUR: 22.5 GRAMS	SULFUR: 25 GRAMS	SULFUR: 27.5 GRAMS
6 % SULFUR	**6-1/2% SULFUR**	**7% SULFUR**
NITRATE: 391.7 GRAMS	NITRATE: 389.6 GRAMS	NITRATE: 387.5 GRAMS
CHARCOAL: 78.3 GRAMS	CHARCOAL: 77.9 GRAMS	CHARCOAL: 77.5 GRAMS
SULFUR: 30 GRAMS	SULFUR: 32.5 GRAMS	SULFUR: 35 GRAMS
7-1/2 % SULFUR	**8% SULFUR**	**8-1/2% SULFUR**
NITRATE: 385.4 GRAMS	NITRATE: 383.3 GRAMS	NITRATE: 381.2 GRAMS
CHARCOAL: 77.1 GRAMS	CHARCOAL: 76.7 GRAMS	CHARCOAL: 76.3 GRAMS
SULFUR: 37.5 GRAMS	SULFUR: 40 GRAMS	SULFUR: 42.5 GRAMS
9 % SULFUR	**9-1/2% SULFUR**	**10% SULFUR**
NITRATE: 379.2 GRAMS	NITRATE: 377.1 GRAMS	NITRATE: 375.0 GRAMS
CHARCOAL: 75.8 GRAMS	CHARCOAL: 75.4 GRAMS	CHARCOAL: 75.0 GRAMS
SULFUR: 45 GRAMS	SULFUR: 47.5 GRAMS	SULFUR: 50 GRAMS

Each of these recipes will make 500 grams (a little over a pound) of propellant, and you can scale them up or down according to your needs. Set up your powder mill according to the instructions in the general text. Pick the powder recipe that you wish to work with, and follow a 12-hour milling schedule.

Grind the potassium nitrate beads for 4 hours. Remove them from the mill, and store the ground-up nitrate powder in a sealed container. Fill the mill with the proper amount of charcoal and grind it for 2 hours. Open the mill, reintroduce the previously ground potassium nitrate, add the sulfur, and mix all three ingredients together for another 6 hours. Open the mill, and remove the finished gunpowder. Store it in a moisture-proof container until you're ready to use it.

To remove any of the ingredients or finished gunpowder from the mill, simply dump the entire contents, brass pellets and all, into a plastic kitchen collander (a big bowl with holes in it) over a couple sheets of newspaper, sift the pellets clean, and dump them back into the mill.

WATCH OUT FOR STATIC ELECTRICITY!

Pick up the newspaper, and holding it like a trough, carefully pour the contents in question into a suitable container.

NOW, IF YOU'VE BEEN WONDERING WHETHER OR NOT YOU CAN USE CRYSTALLINE OR POWDERED FORMS OF POTASSIUM NITRATE AND CHARCOAL IN YOUR PROPELLANT, THE ANSWER IS YES, OF COURSE.

When we originally checked into the availability of potassium nitrate, we found that in some areas the PRILLED grade was the only form available. The prilled grade is ACTUALLY the most inconvenient form to use, as it is the most difficult to grind up. The same applies to the chunk form of the charcoal, and if you can obtain the powdered forms of either of these ingredients by all means USE THEM! You will be able to cut several hours off of your milling schedule by beginning with these finely divided materials.

Here's another tip on powder handling. Let's assume that you've dampened a batch with the required 8 teaspoons of water per pound, but have been called away to another task, and realize that you will not be able to use it until later in the afternoon, or perhaps the next day.

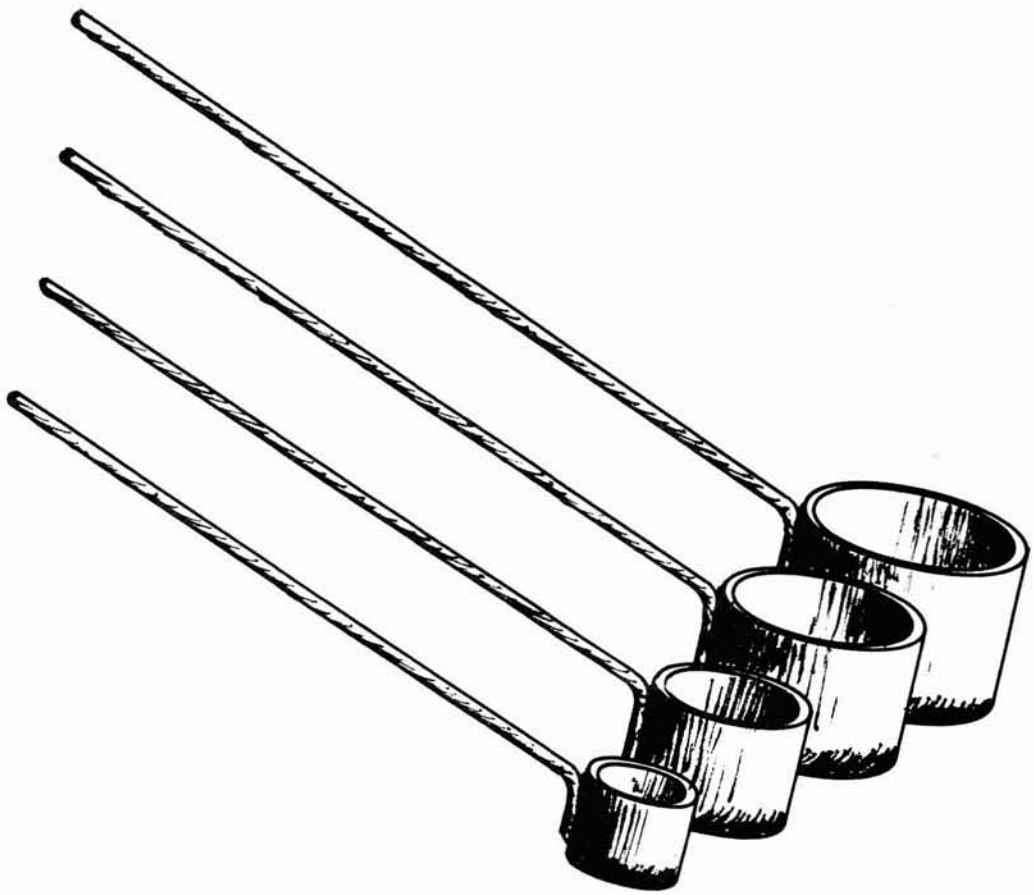
In such a case, you should reseal the bowl with its own tight fitting lid or Saran Wrap, and place it in a refrigerator. The tight seal and low temperature will virtually eliminate evaporation from the powder, and it should keep well enough to use for several days.

APPENDIX C

ADDITIONAL TIPS ON LOADING AND TAMPING

You must always load the powder in accurately measured doses. To do this you make yourself a little set of powder scoops as follows (See FIGURE 29).

FIGURE 29



You make these scoops from copper water pipe caps. You can purchase them in any hardware store. Solder each copper cap to a handle made from a length of thick brass "brazing rod". Use a 1/2" pipe cap for your 1/2" casings, a 3/4" cap for your 3/4" casings, a 1" cap for your 1" I.D. casings, and a 1-1/4" cap for your big 1-1/8" "SUPER-G" engines.

As you load and tamp your motors use the following procedure. If you like, you can attempt to weigh out enough of the powder for exactly one rocket motor, although after you've gained some experience, you will find that this is unnecessary. Scoop out equal doses of propellant for tamping. The D-18 booster will require about 6 scoops from the 3/4" pipe cap. The giant "G" booster will require about 14 scoops from the 1" cap, and the "SUPER-G" engine will take 10 or 12 doses from the 1-1/4" cap.

Tamp each dose firmly, and as you finish up your tamping operation, watch out for the following phenomenon. You may notice a hairline crack or separation between the freshly tamped end of the propellant charge and the inside wall of the engine casing. If you've done everything correctly, and you see this separation, it is more than likely superficial, and in such a case it will automatically close, or "seal up" during the curing process.

If may, however, indicate one or two OTHER things that can be serious. Either you didn't add enough water to your gunpowder before tamping, or you didn't tamp the propellant HARD enough, or perhaps a little of both.

The BEST way to handle such a motor is to go ahead and dry it out and see what happens. If the crack seals up tight, the motor will be safe to fire. If not, the propellant pellet will be blown out the front of the engine like a ROMAN CANDLE.

If you begin to encounter this problem, try the following. FIRST try tamping harder. As you make your next motor, either tamp harder, or use more hits per dose of powder. If this resolves the problem, you're home free. This harder tamping SHOULD cause the following phenomenon. As you remove the coring pintle from the finished engine, you will begin to find it coated with little "glops" of wet gunpowder. This means that you're now tamping hard enough that you're actually squeezing a little water out through the center of the propellant charge. A small amount of this is DESIRABLE. It lets you know that you're doing the job right, and it leaves a rough interior to the propellant core which actually aids in the spread of the initial ignition.

If you're REALLY TAMPING HARD, and you still encounter a dry propellant coring pintle, and casing-propellant separation, then add another teaspoon of water (to a one pound batch). This should solve the problem, and you should be on your way to success.

If you notice that the freshly tamped end of the propellant charge "bloats" and swells into a dome shape soon after tamping, then try cutting back 1/2 teaspoon or 1 full teaspoon of water per pound. You can do this by weighing what you've got left and adding the proper amount of dry powder to the bowl to achieve the desired moisture content. With some practice you should be able to achieve a reasonably smooth propellant core AND a tight seal between the propellant charge and the interior wall of the motor casing.

NOZZLE DISTORTION

Remember that when you built your rocket engine, the powder was wet and the clay nozzle was dry. As the engines cure, some of the moisture in the gunpowder will be absorbed by the dry (and thirsty) clay, and this sudden influx of water will cause the nozzle to distort.

The phenomenon is not really noticeable in the little half inch cased motors, but as you being increasing engine diameter, it can have a remarkable effect on the finished dimensions of your engines. The water first enters the clay and distorts its structure (through swelling), and later in the curing process leaves the clay with the result that the nozzle diameter is reduced by quite a few percent. The big "G" and "SUPER-G" engines operate with a 9/16" diameter nozzle throat, and moisture distortion will reduce this to 1/2" or less in the finished motors.

This situation cannot be tolerated, and you can prevent it by simply sprinkling a small amount of shaved candle wax into the engine casing just before adding the first dose of dampened gunpowder (See FIGURE 30 on page 16). You can shave the wax from an old candle with a kitchen grater (the kind that you use to make shredded carrot salad).

Next place the cored tamping tool into the casing on top of the wax, and give it three or four good, solid hits. Finish the job (See FIGURE 31) by pressing and twisting the tool firmly against the inside surface of the nozzle clay. This will rub the shaved wax into the surface structure of the nozzle and create a moisture-proof barrier between it and the dampened gunpowder. When you're finished, you can clean any residual wax off of the tamping tool with a razor blade or a pocket knife. The little half inch motors will take just a pinch of wax. The 1" and 1-1/8" motors will require perhaps a half teaspoon. We do this routinely on all of our motors, and since we began this practice, we've virtually eliminated nozzle distortion.

If you allow your finished engines to air-cure at room temperature, the wax layer will remain solid. However, if you cure the motors in a dehydrator at an elevated temperature, the wax will soften, and as it softens it will ooze out from its location between the nozzle and the gunpowder, developing a wax constriction in the nozzle throat.

This phenomenon looks a little strange, and during engine ignition it is incinerated and blown out the nozzle so rapidly that it has little effect on motor performance. If, however, it seems excessive, or if it interferes with the insertion of the igniter, you can simply cut it away with an X-Acto knife.

FIGURE 30

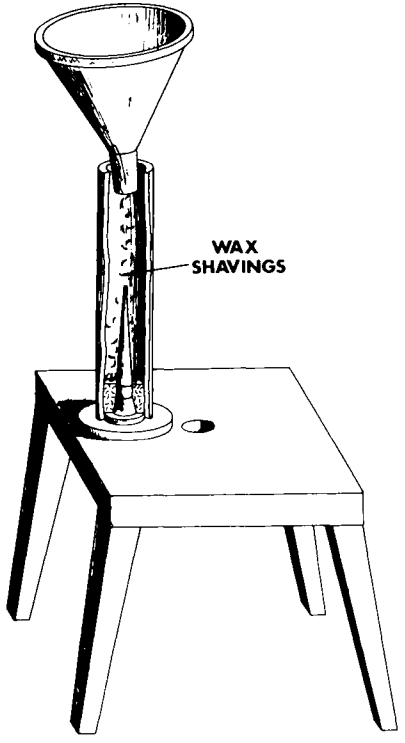
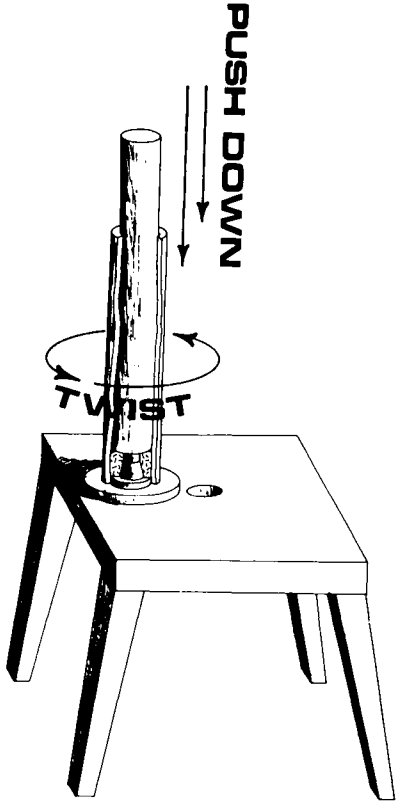


FIGURE 31



THE STATIC TEST STAND

It might seem easy to gauge engine performance by simply watching various rockets in flight and picking the one that performs the best. In most cases for sporting purposes this method will suffice.

If, however, you wish to really fine-tune your engine designs, you're going to need a way to accurately (or at least reasonably accurately) measure motor performance in a scientifically controlled situation.

You can build yourself a safe-to-operate static test stand with a real recording dynamometer, and you don't need to buy a lot of expensive equipment to do so. The one we've designed can, in most cases, be built entirely with the scrounged materials normally found at yard sales and swap meets. The design is extremely flexible, and you DON'T have to build it exactly as we've shown it. The version illustrated in FIGURE 32 features a heavy, bolted-together steel channel iron base, but you COULD simply sink the vertical thrust beam supports into the ground with concrete and eliminate much of the expense of the basic support structure.

The advantage of the bolted-together model, aside from its being portable, is that the locations of the engine cradle and the kitchen scale can be easily changed to obtained readings in a number of different thrust ranges, thus making the apparatus adaptable to engines both small AND large.

The illustration of the completed unit (FIGURE 32) should be self-explanatory. The engine hangs from the thrust beam in a specially designed cradle. It points DOWN into a pipe in the ground, and the blast deflector keeps engine exhaust from hitting the beam.

When the motor is fired, it pulls DOWN on the thrust beam, which in turn presses down on a common, spring operated 25 pound kitchen scale. A felt-tipped "FLAIR" pen moves up and down along with the engine AND the beam and records its activities on a strip of paper wrapped and taped around a large fruit cake tin driven by a Bar-B-Que motor. The flair pen is firmly affixed to a small C-clamp via vinyl plastic electrical tape, and then clamped firmly to the thrust beam in a location most convenient for the particular engine that you're testing (you'll have to experiment a bit to find the proper place on the beam).

Don't laugh! It works! There is a little bit of wobble in the bearing of the Bar-B-Que motor, but that wobble is continuously removed by a small ball bearing mounted on the end of a springy wire (ours is made from a coat hanger). The ball bearing presses down on the outside of the top of the cake tin and removes the slack from the system as the cake tin rotates.

The cake tin-Bar-B-Que motor assembly (FIGURE 33) is screwed to a piece of 3/4" plywood via three extra mounting holes (you'll have to drill them yourself) in the face plate of the motor, and the entire assembly, barring a more elaborate

ITEM	REQ'D	DRAWING NO.	NAME
A	1	01-84-002	LEFT BASE RAIL
B	1	01-84-003	RIGHT BASE RAIL
C	1	01-84-004	FRONT RAIL
D	1	01-84-005	BACK RAIL
E	1	01-84-006	LEFT VERTICAL SUPPORT
F	1	01-84-007	RIGHT VERTICAL SUPPORT
G	2	01-84-008	HORIZONTAL X-BRACE
H	2	01-84-009	VERTICAL X-BRACE

ITEM	REQ'D	DRAWING NO.	NAME
J	2	01-84-010	DIAGONAL BRACE
K	1	01-84-011	THRUST BEAM
L	1	01-84-013	THRUST BEAM BRACE
M	1	01-84-012	THRUST BEAM FOOT
N	1	01-84-014	BEAM FOOT BRACE
O	1	01-84-015	THRUST BEAM SHAFT
P	1 Ea.	01-84-016	BEAM SHAFT SPACERS

FIGURE 32

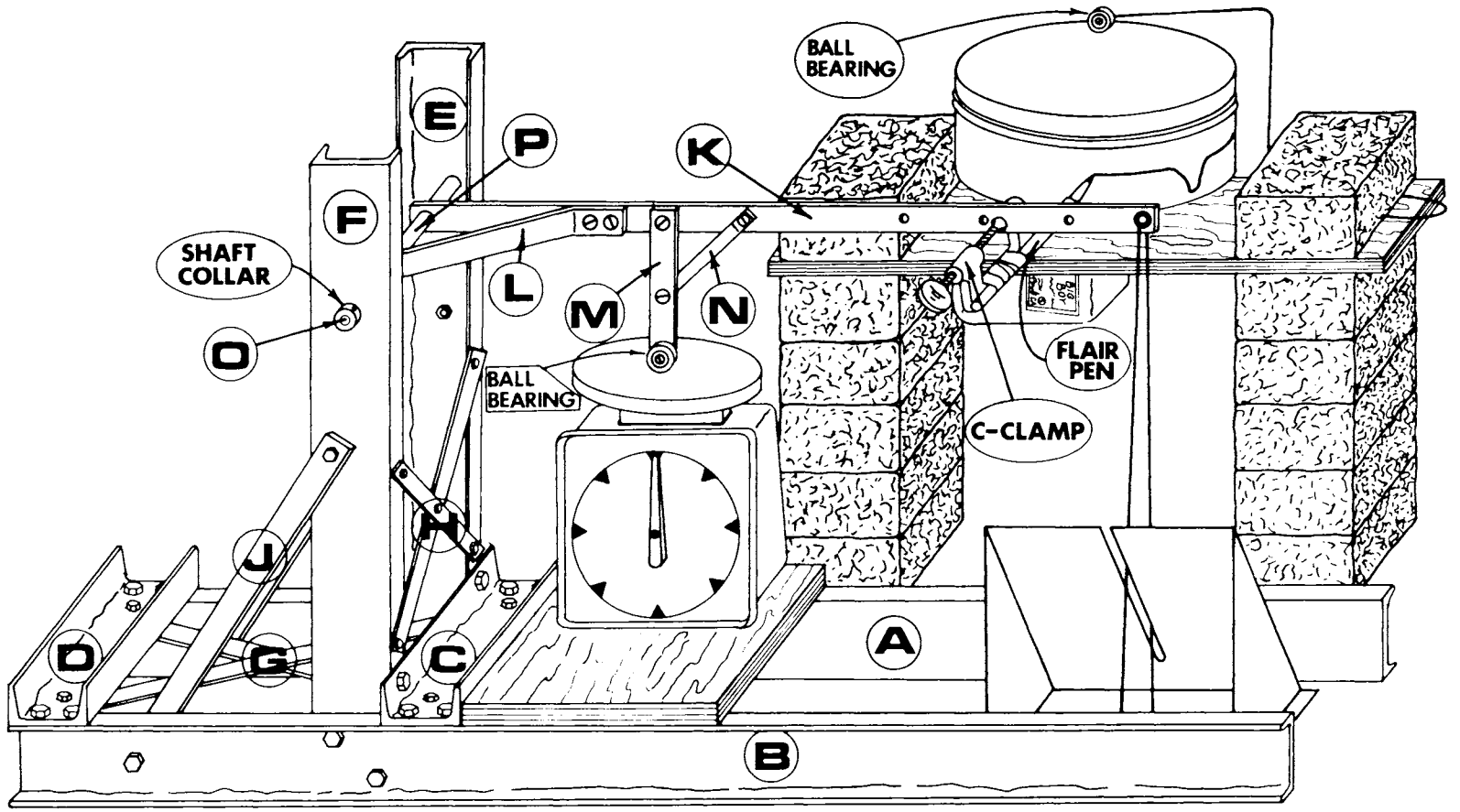
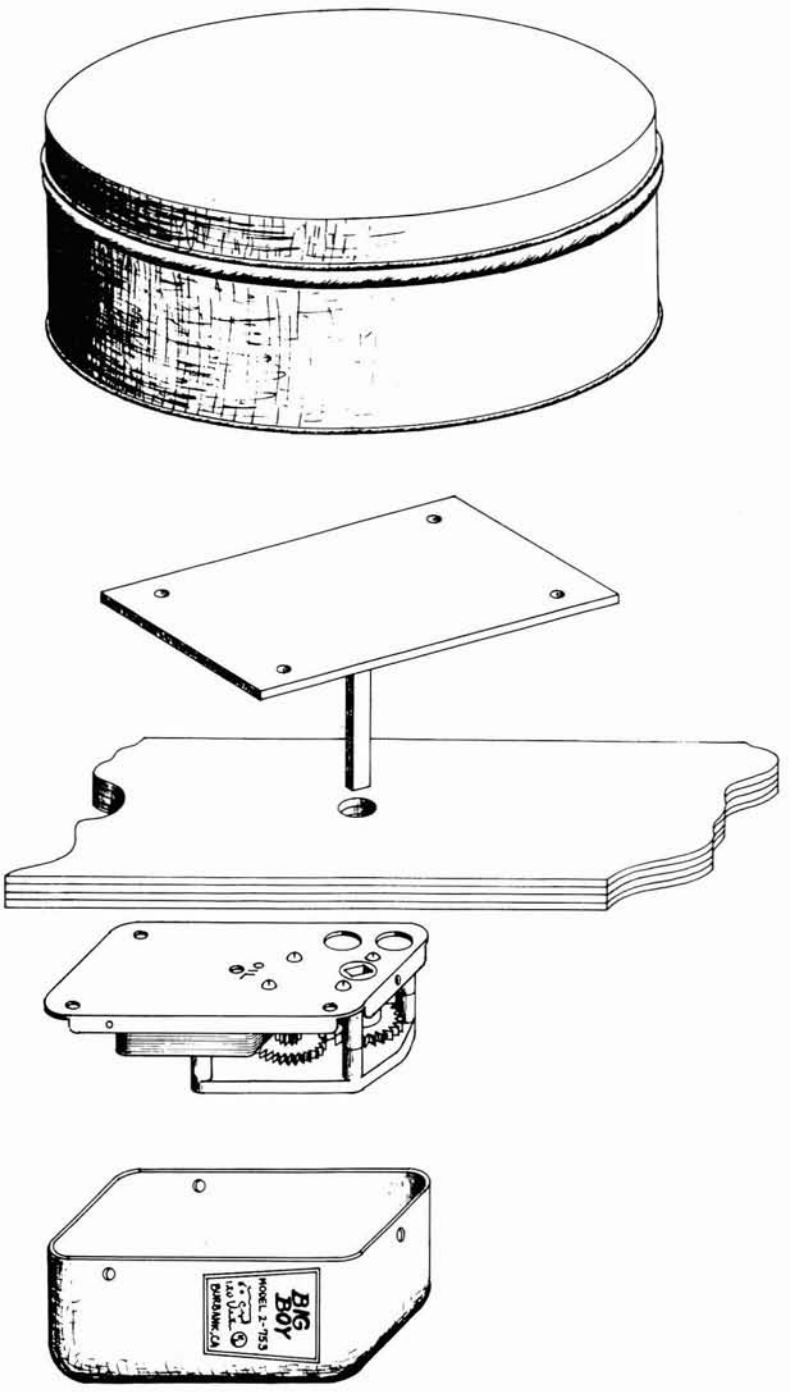


FIGURE 33



and creative arrangement, can be held firmly in place on a pile of bricks. When the apparatus is not in use, the recording equipment is slid away from the thrust beam, and the flair pen is capped.

When the time arrives for an engine to be tested, the drive motor is turned on, the pen is uncapped, and the recording drum is slid into position until the pen makes good contact with the paper and leaves a clear base line around the entire circumference of the chart.

Once the baseline is established, the experimenter moves to a safe location and remotely fires the engine. When the test is finished, the chart drum is slid away from the pen, the pen is capped, the drive motor is shut down, and the paper record of events is removed from the drum and taken to the lab for analysis.

We purchased everything but the channel iron and bricks at garage sales. The kitchen scale cost $5. The Bar-B-Que motor cost $2, and the cake tin was 25¢. The Bar-B-Que motors normally cost $25 or $30 new, but people hardly every use them. The Bar-B-Que itself usually rusts through after years of use, and they haul it to the dump. For some reason they never have the heart to throw away the interesting little motor, and it usually gets relegated to a box on a shelf in a closet.

The support structure is built of steel (it should be MASSIVE and rigid), and the thrust beam is made of aluminum (it should be LIGHT and rigid). You can use your imagination in designing the engine cradle. We made ours by wrapping a coil of 1/8" dia. steel rod around one of our engine casings. When you release the rod, the coils spring open a bit, allowing enough room for the engine to slide freely in and out. You can then braze the coils to two straight rods which hinge on a pin on the thrust beam. A steel washer brazed to the bottom of the coil supports the front of the motor.

REMEMBER THIS THOUGH! When testing a paper-cased rocket engine, you should not wrap anything tightly around the casing or stuff the engine into a tight-fitting tube. This would support the walls of the casing during the test, and an engine that might explode when mounted in an unconfined condition in a finished rocket would erroneously not explode and be deemed a safe design. If the motor design is going to self-destruct, you want it to do so during static testing and NOT after you've placed it in a nicely built model.

Our Bar-B-Que motor is a "Big Boy". It drives the chart drum (cake tin) via a little 5/16" square keyway connected to the motor inside the housing. We've connected the motor keyway to the chart drum through a 5/16" square shaft brazed to a flat sheet steel flange bolted to the bottom of the drum.

Before you can use such a motor, you must find out how fast it turns. If it has an oil hole, squirt a drop or two of oil in the appropriately marked spot, plug the motor in, and let it warm up for a few minutes. When you're certain that it's "up to speed", count how long it takes to make 50 revolutions.

The "Big Boy" that we use takes 10 minutes and 27 seconds, or 627 seconds total. Divide the total number of seconds by the number of revolutions (50), and you will obtain the number of seconds required for the motor shaft to make one turn. Our motor accomplishes this in 12.54.

In order to accurately use the chart apparatus, you must know the linear rate at which the chart is moving under the pen. Our cake tin is exactly 10 inches in diameter. Measure the diameter of yours and obtain the circumference by multiplying by 3.14 (Pi). In our case the answer is 31.4 inches.

Since our drum makes one entire revolution every 12.54 seconds, and since the chart wrapped around the drum is 31.4 inches long, the chart is traveling at a rate of 2.5" per second. Knowing this, we can make notes of exact burn times. That is, if the entire graph of the engine burn is, say, 1-1/4 inches long, we can calculate (1-1/4 inches divided by 2.5 inches per second) the total burn time to be 0.5 seconds.

The blast deflector can be bent or fabricated from any heavy gauge sheet metal. If you bend a little flange onto the base of each side of the deflector, you can set a brick on each flange to hold it down during the duration of the engine test.

To find out the maximum thrust achieved for a given burn, plug the chart recorder in and rotate it back to the position of maximum thrust. Press the thrust beam down on the kitchen scale until the pen touches the highest point on the thrust graph. If the scale is now reading, for example, 12 pounds, you can calculate the actual maximum thrust achieved by your rocket motor, and this final figure will depend upon where along the thrust beam the kitchen scale is located in relation to the engine cradle.

FIGURE 34 on the next page illustrates the six possible combinations of motor and scale position. There are three primary locations along the beam, and they are labled A, B, and C. A multiplication factor is given for each arrangement. To find the actual peak thrust simply multiply the reading on the scale by the listed factor, and write the actual maximum thrust figure on the chart for later reference.

Items such as the kitchen scale, cake tin, and Bar-B-Que motor can be purchased. Other parts of the apparatus must be built, and following FIGURE 34 we've provided you with a full set of shop drawings needed to build the chart recorder flange and test stand itself.

The test stand itself is built primarily of standard "3 inch" channel iron, and it would seem that measurements such as "one inch, one half inch, etc." would be satisfactory to use in the construction. Unfortunately "standard 3 inch" channel iron is ACTUALLY 2-15/16" wide by 1-7/16" thick, and unless you take these odd measurements into account when you drill your bolt holes, none of the holes will line up properly. Pay attention to the measurements on the drawings and try to drill the holes as close to their designated locations as possible.

Use standard hardware store nuts and bolts, and give the setup a good coat of paint if you wish. Take care of it, and it should last for many years. Please note that the spent motors should be removed from the cradle, and the cradle and blast deflector should be thoroughly washed after each series of tests. The exhaust products of black powder rocket engines are hygroscopic (they absorb water out of the air) and CORROSIVE. If you let your equipment sit uncleaned for 24 hours, you will return to find a healthy "bloom" of rust growing on everything that the engine exhaust touched.

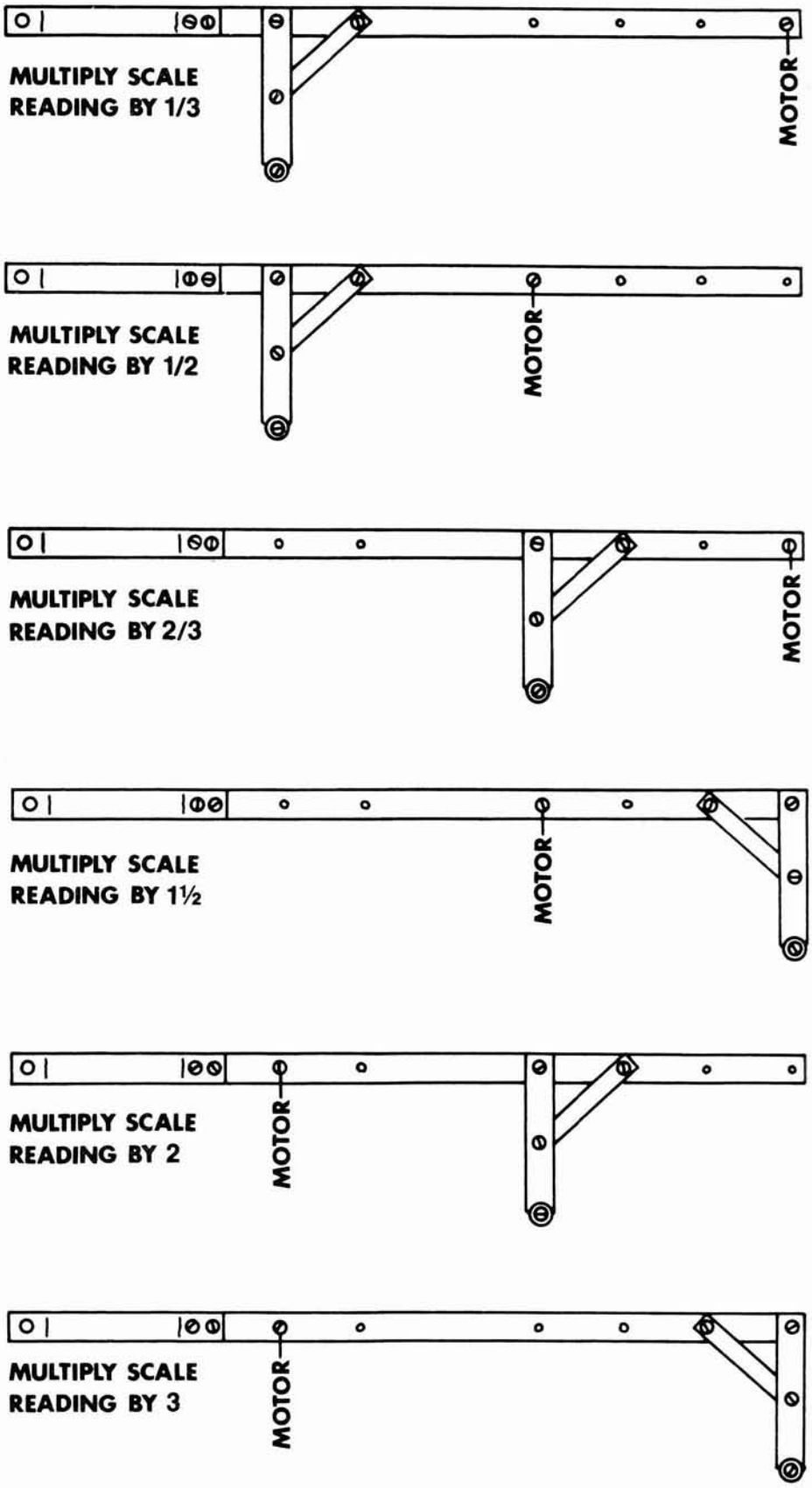

MULTIPLY SCALE READING BY 1/3
MOTOR
MULTIPLY SCALE READING BY 1/2
MOTOR
MULTIPLY SCALE READING BY 2/3
MOTOR
MULTIPLY SCALE READING BY 1½
MOTOR
MULTIPLY SCALE READING BY 2
MOTOR
MULTIPLY SCALE READING BY 3
MOTOR

FIGURE 34

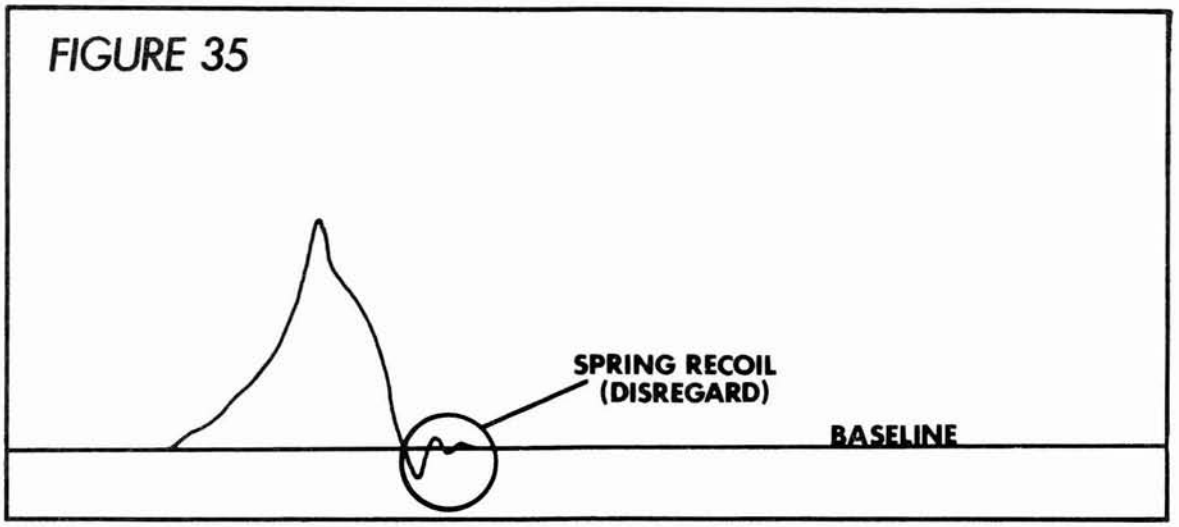
Once you've obtained a chart recording of a successful engine burn, you can analyze it to obtain PEAK THRUST, AVERAGE THRUST, TOTAL BURN TIME, TIME TO PEAK THRUST, and TOTAL IMPULSE.

Measurement of PEAK THRUST is simple. As stated on page 21 of these appendices, press down on the thrust beam and multiply the scale reading by the appropriate multiplication factor listed in FIGURE 34.

TOTAL BURN TIME and TIME TO PEAK THRUST can be figured by measuring the horizontal distance on the chart from the beginning of the burn to the desired data point and dividing that distance by the rate that the chart is moving in inches per second.

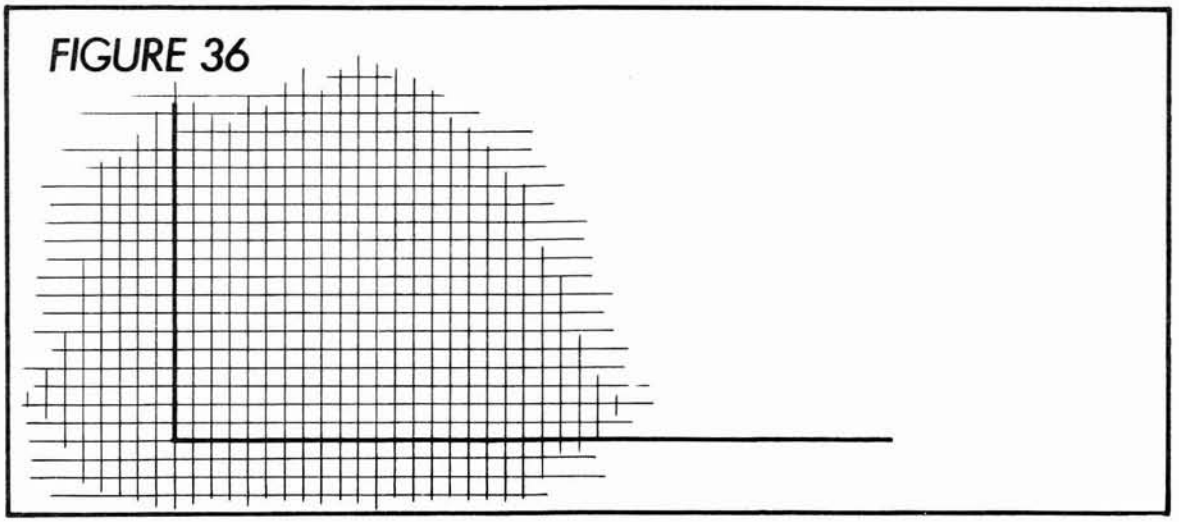
AVERAGE THRUST and TOTAL IMPULSE are a little trickier to obtain. We'll deal with TOTAL IMPULSE first. Before you can begin, you must transfer the chart graph onto transparent tracing paper, but that's easy to do. Just lay the chart on your desk and TRACE IT. FIGURE 35 below is the tracing of an engine similar to the one described in CHART THREE on page 15 in the main text.

FIGURE 35

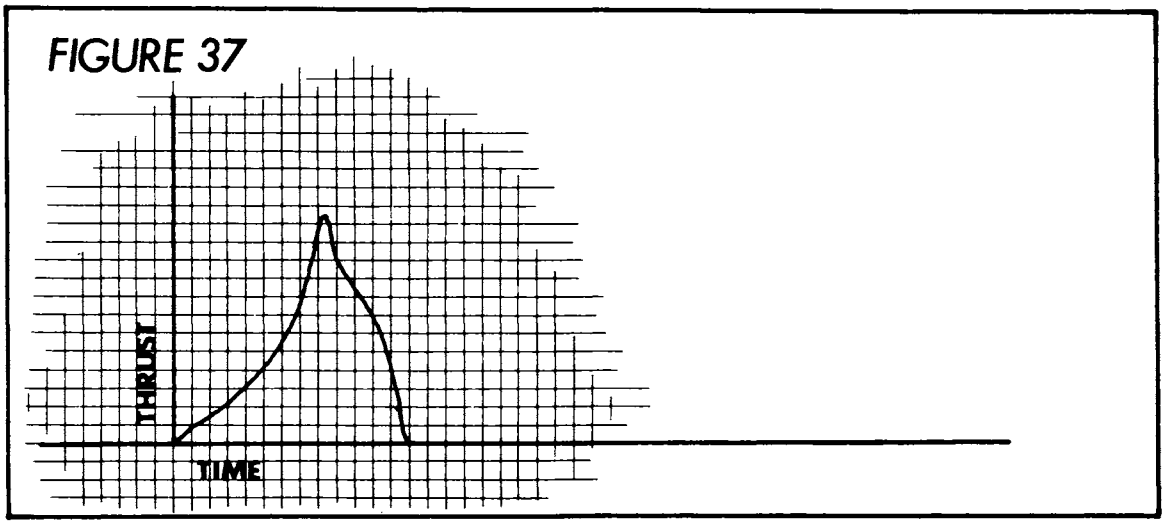


Next obtain a piece of quadrille-ruled graph paper, and draw on it (See FIGURE 36) a horizontal and a vertical axis, so that the two intersect as shown.

FIGURE 36



Superimpose the chart tracing on the graph paper so that the chart base line lines up with the horizontal axis, and the beginning of the burn falls on the intersection of the two axes (See FIGURE 37). A ten-to-the-inch ruling is best and will give you the most accurate results.



The horizontal axis represents burn time, and the vertical axis represents engine thrust. Remember that the chart was traveling (in our case) 2-1/2 inches per second. Since the graph paper is ruled in tenths of an inch, each little square along the horizontal axis represents (1/10 divided by 2.5) .04 seconds.

The distance along the vertical axis from the base line to peak thrust is approximately 1-1/4 inches, and since that measurement represents 12-1/2 pounds of thrust, we divide that amount by the total number of squares (tenths of an inch) between the base line and that peak. In this case each tenth of an inch vertically just happens to represent (12.5 divided by 12.5) (12.5 tenths of an inch is 1-1/4 inch) 1.00 pounds.

Engine impulse at any given moment in the burn is the product of the thrust at that moment multiplied by the time increment in question. Therefore, each little square on the graph paper represents (1.00 pounds X .04 seconds) 0.040 pound-seconds of impulse. To find the total impulse we simply count all the squares under the thrust curve. Half squares are added up, and little corners of squares are tallied along with "almost-whole" ones to arrive at the total figure. In FIGURE 38 we've checked them all off, and you'll see a few vacant spaces. These vacant parts of squares were tallied with other parts of squares until a whole was obtained. One of the parts in the tally was then marked to represent that whole, and you can see that the grand total is SIXTY FOUR (64).

Since each square is equivalent to 0.040 pound-seconds of impulse, we can obtain the total impulse by multiplying that figure by 64. The result is 2.56 pound-seconds total impulse. Translated into metrics (a pound-second is equal to 4.45 newton-seconds), the result would be 11.4 newton-seconds.

The commercial hobby industry has a system of rating motor performance based upon total engine impulse and average thrust. The system is metric, so thrust is measured in newtons (4.45 newtons per pound), and impulse is measured in newton-seconds (4.45 newton-seconds per pound-second).

If you purchase a commercially made engine in a hobby shop, the motor that you buy will have a letter-number code printed on it, i.e. "D-12-6". The letter

indicates the total impulse, the number in the middle indicates the average thrust in newtons, and the last number indicates the number of seconds in the pre-recovery time delay, if there is one. A booster engine would be labeled "D-12-0".

FIGURE 38

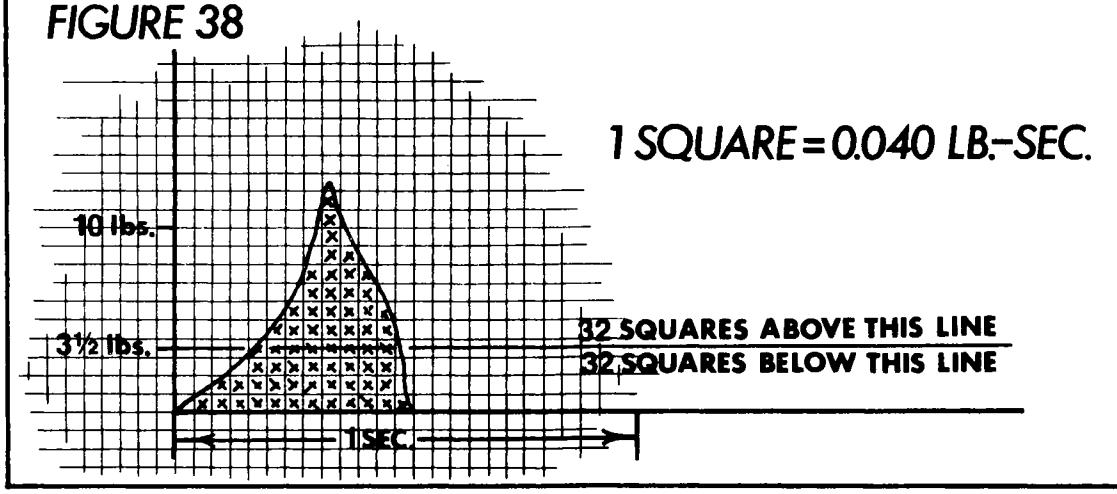


CHART 4 below illustrates the system. Amateur rocket enthusiasts who work beyond the accepted bounds of "model rocketry" have extended the system as shown in CHART 5.

CHART 4

ENGINE SIZE	TOTAL IMPULSE (nt.-secs.)	(lb.-secs.)
A	1.26 to 2.50	0.29 to 0.56
B	2.51 to 5.00	0.57 to 1.12
C	5.01 to 10.00	1.13 to 2.24
D	10.01 to 20.00	2.25 to 4.48
E	20.01 to 40.00	4.49 to 8.96
F	40.01 to 80.00	8.97 to 17.92

CHART 5

ENGINE SIZE	TOTAL IMPULSE (nt.-secs.)	(lb.-secs.)
G	80.01 to 160.00	17.93 to 35.96
H	160.01 to 320.00	35.97 to 71.92
I	320.01 to 640.00	71.93 to 143.83
J	640.01 to 1280.00	143.84 to 287.65

You can see from CHART 4 that the engine that we've just tested falls into the "D" category, since it has a total impulse of 11.4 newton-seconds. To find the average thrust, start at the base line, and count up HALF the total number of squares under the thrust curve (See FIGURE 38). The number is 32. By drawing a horizontal line from this level over to the vertical axis, you can see that the average thrust is approximately 3-1/2 pounds (16 newtons). The total impulse of 11.4 newton-seconds and the average thrust of 16 newtons make our engine a "D-16" according to commercial standards.

There is quite a bit of inertia in the moving parts of this test stand. It takes a fraction of a moment for the thrust beam to start moving, and once in motion, it takes a fraction of a moment to stop. This phenomenon will cause all your thrust curves to appear a little lop-sided, but the effects will average out to a reasonable extent, and this equipment, when properly set up and operated, will give you MORE than enough data to refine your engine construction to the levels desired.

We suggest that you obtain a few commercially made engines and test THEM on your newly built equipment. As stated in the main text, we always obtained lower readings than the companies in question actually claimed in their catalogues. By testing one of theirs AND one of yours, you'll gain a truer picture of just how well your motors stack up against theirs.

A common kitchen scale will weigh up to 25 pounds, and since the greatest multiplication factor for this particular thrust beam is 3, the system has an upper limit of 75 pounds. By completely reversing the scale and carriage positions you can obtain a multiplication factor of just 1/3 and a corresponding upper limit of about 7 pounds, perfect for testing a tiny A-3.

When testing ANY motor, operate according to the following sequence of events. First make sure that the firing mechanisms are DISCONNECTED and DISARMED. Next place the motor in the carriage and adjust the "tare adjustment" on the kitchen scale (the motor will add weight to the system, and you'll have to rezero the scale each time you change engine sizes).

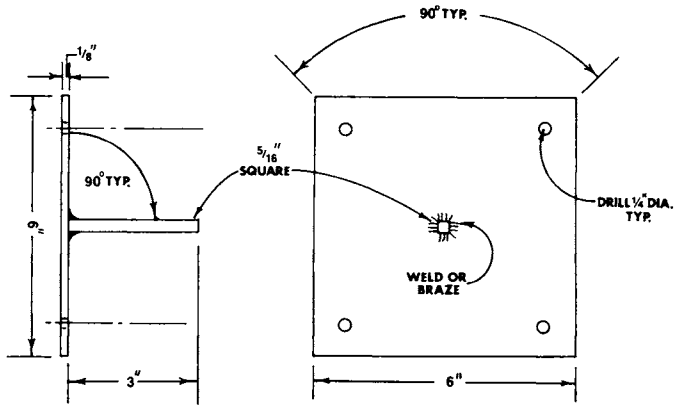
Connect the firing clips to the engine igniter, position the blast shield, and turn on the chart drive motor.

Position the pen against the paper, establish a baseline, remove yourself to a safe location, arm the firing system (the arming switch should be located AWAY from the test stand in the observation area), and remotely fire the motor.

Immediately upon completion of a test, disarm the firing system, remove the motor from the engine cradle, remove the chart from the drum, and prepare the equipment for the next test, or clean it for storage.

With a little practice, you'll be able to fit several tests onto one chart of paper. To do this, simply mark the end of the most recent test clearly with a marking pen. Wait for the chart to rotate to an unused area, and press the firing button. By using this method, we've been able to pack as many as six tests onto one strip of paper.

PLEASE NOTE: Look in the stationery section in your local dime store. You will find a selection of paper calculator printout tapes. The standard ones are 2-1/4 inches wide, and they fit perfectly around the circumference of a 10" diameter cake tin.



TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: CHART DRUM FLANGE (for a 10 inch dia. drum)	
SHEET 1 of 1	01-84-001
SCALE: 1/4	

MATERIAL: STEEL

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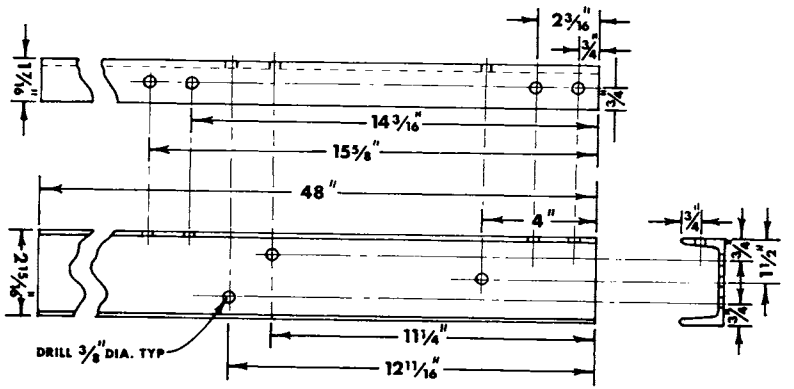

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: LEFT BASE RAIL	
SHEET 1 of 1	01-84-002
SCALE: 1/6	

MATERIAL: STEEL CHANNEL IRON (3 inch)

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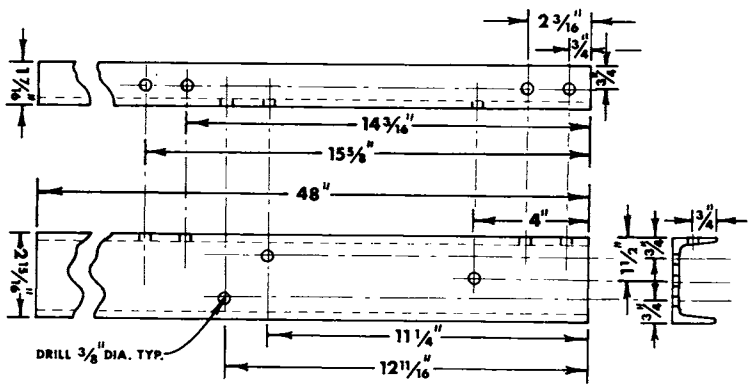

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: RIGHT BASE RAIL	
SHEET 1 of 1	01-84-003
SCALE: 1/6	

MATERIAL: STEEL CHANNEL IRON (3 inch)

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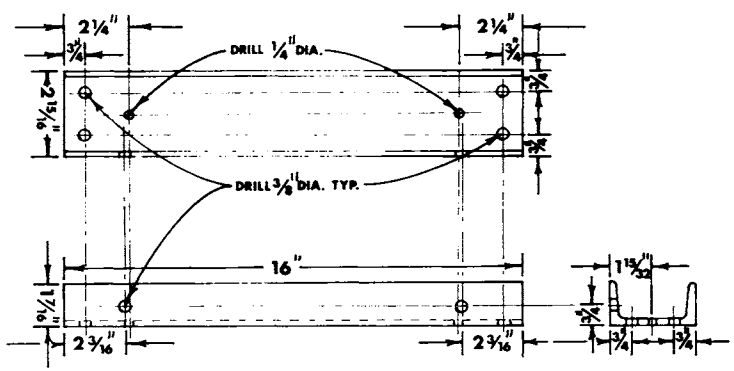

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: FRONT RAIL	
SHEET 1 of 1	01-84-004
SCALE: 1/6	

MATERIAL: STEEL CHANNEL IRON (3inch)

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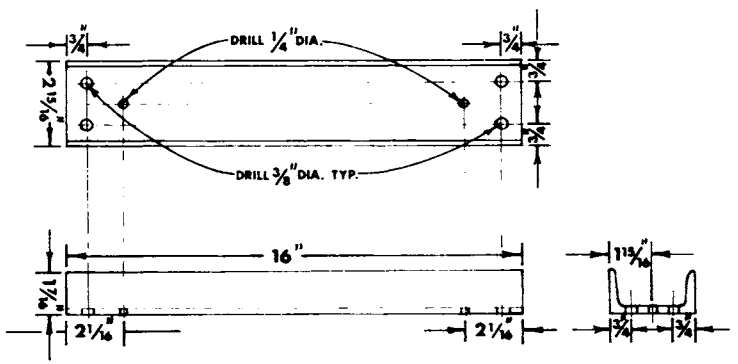

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: BACK RAIL	
SHEET 1 of 1	01-84-005
SCALE: 1/6	

MATERIAL: STEEL CHANNEL IRON (3 inch)
MATERIAL:

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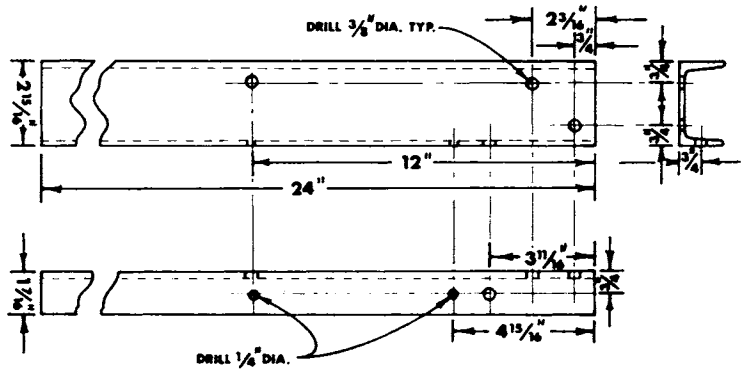

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: LEFT VERTICAL SUPPORT	
SHEET 1 of 1	01-84-006
SCALE: 1/6	

MATERIAL: STEEL CHANNEL IRON (3 inch)

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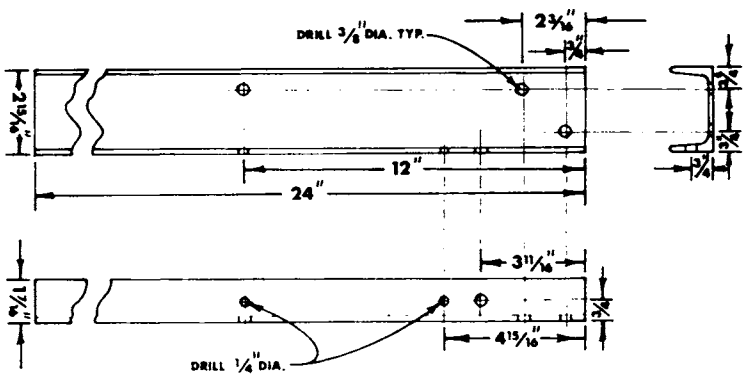

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: RIGHT VERTICAL SUPPORT	
SHEET 1 of 1	01-84-007
SCALE: 1/6	

MATFRIAL: STEEL CHANNEL IRON (3 inch)

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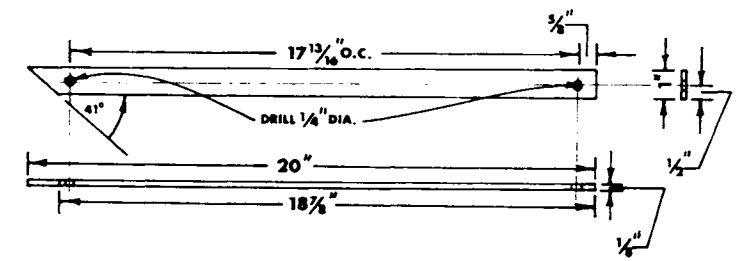

TELEFLITE CORPORATION	
UNIT: STATIC TEST STAND	
NAME: HORIZONTAL X-BRACE (2 REQUIRED)	
SHEET 1 of 1	01-84-008
SCALE: 1/6	

MATERIAL: STEEL

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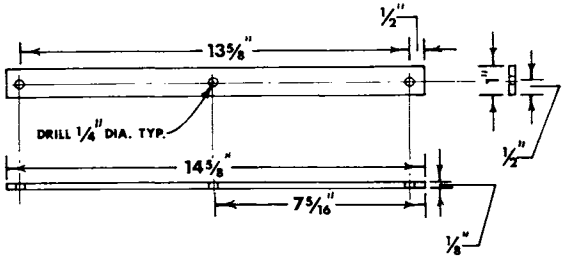

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND
NAME: VERTICAL X-BRACE
(2 REQUIRED)
SHEET 1 of 1
SCALE: 1/6

01-84-009

MATERIAL: STEEL

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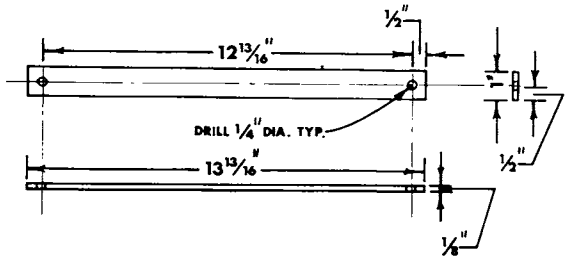

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND
NAME: DIAGONAL BRACE
(2 REQUIRED)
SHEET 1 of 1
SCALE: 1/6

01-84-010

MATERIAL: STEEL

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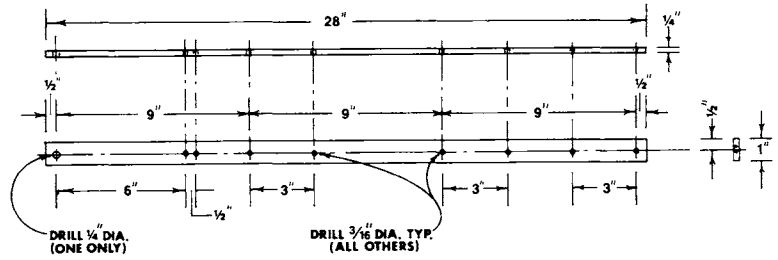

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND
NAME: THRUST BEAM

SHEET 1 of 1
SCALE: 1/8

01-84-011

MATERIAL: ALUMINUM

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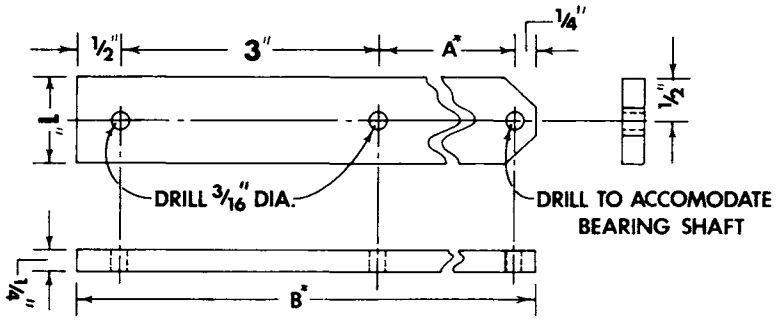

*THESE DIMENSIONS (A & B) DEPEND UPON THE CHOSEN HEIGHTS OF THE THRUST BEAM AND THE SCALE.

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND
NAME: THRUST BEAM FOOT

SHEET 1 of 1
SCALE: 1/2

01-84-012

MATERIAL: ALUMINUM

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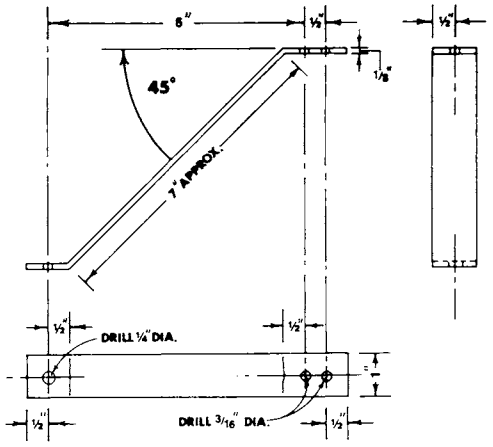

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND

NAME: THRUST BEAM BRACE

SHEET 1 of 1

SCALE: 1/4

01-84-013

MATERIAL: ALUMINUM

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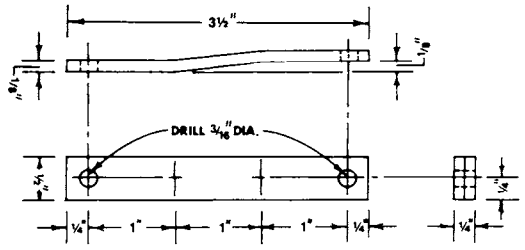

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND

NAME: BEAM FOOT BRACE

SHEET 1 of 1

SCALE: 1/2

01-84-014

MATERIAL: ALUMINUM

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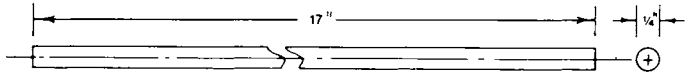

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND

NAME: THRUST BEAM SHAFT

SHEET 1 of 1

SCALE: 1/2

01-84-015

MATERIAL: STEEL

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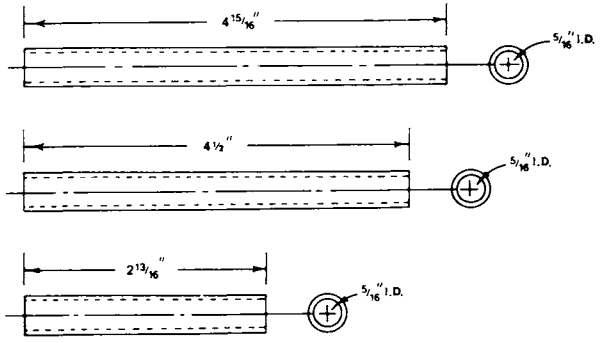

TELEFLITE CORPORATION

UNIT: STATIC TEST STAND

NAME: BEAM SHAFT SPACERS

(one of each required)

SHEET 1 of 1

SCALE: 1/2

01-84-016

MATERIAL: ANY 5/16" I.D. METAL TUBING

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ENGINE PLANS

The following pages will supply you with six full sized cutaway engine drawings, each one illustrating all the critical measurements to be followed in its construction. Engine sizes are A-3, B-7, and C-9, and there are both booster and single (or upper) stage versions of each.

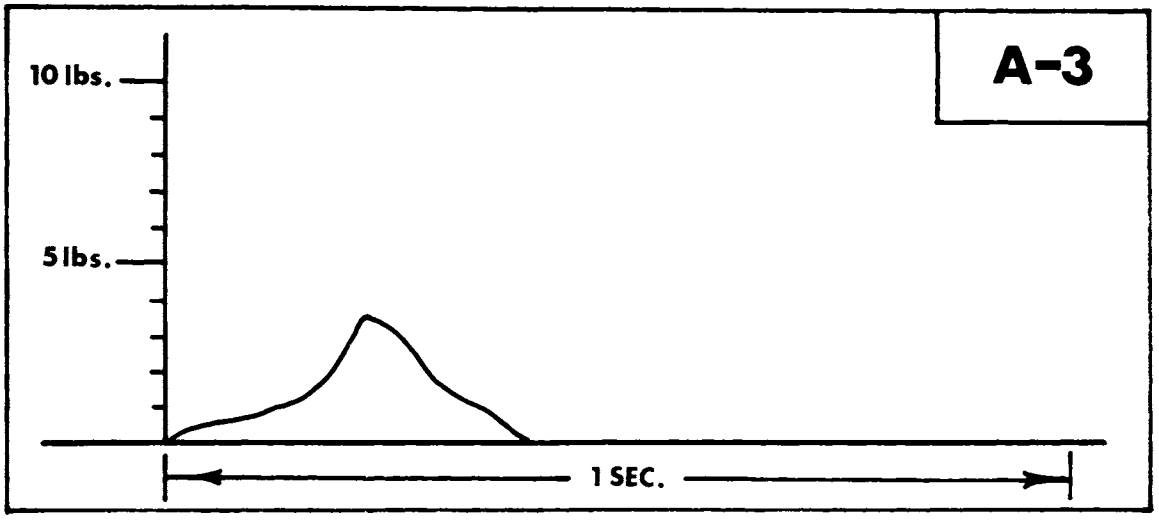
The propellant that you'll be using (approximately 3% sulfur content) burns at a rate of 5 or 6 seconds per inch when unconfined at atmospheric pressure. Use this knowledge to calculate the extra lengths of powder required in the front of these motors to effect the time delays that you desire. For example, and extra half inch of gunpowder grain should add 2-1/2 to 3 seconds. An extra quarter of an inch will add 1-1/4 to 1-1/2 seconds, etc., etc.....

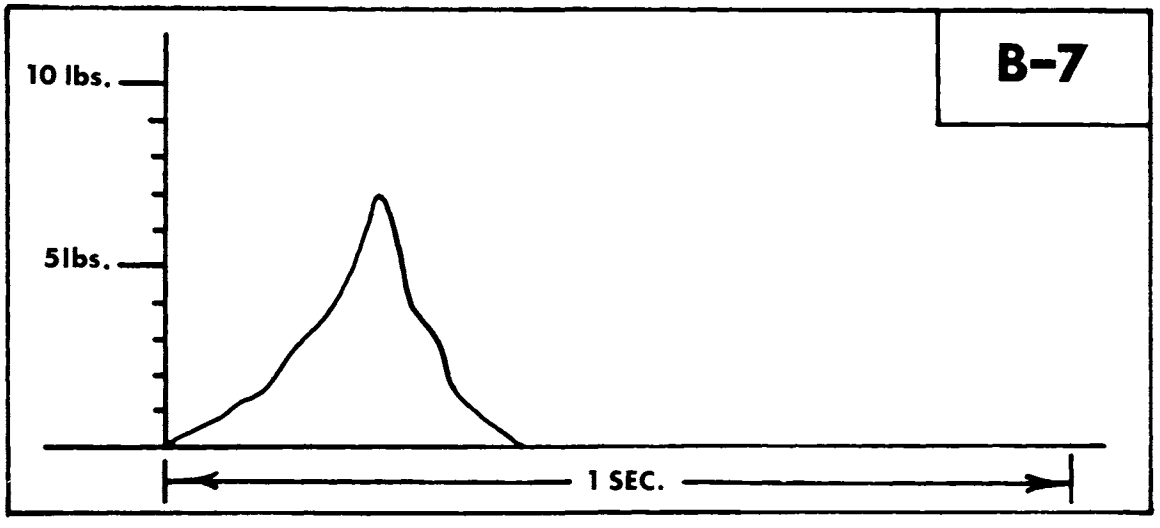
When using the NOZZLE TRIMMER, purchase a small shaft collar (with set screw) and a large "fender washer" (a big flat washer with a little 1/4" diameter hole in it), and slip both over the nozzle trimmer shaft. The washer and adjustable collar can be used as a depth stop to prevent you from cutting deeper than necessary when trimming your nozzles. Set the depth of cut at 2-13/16" for the A-3 motors, 2-7/8" for the B-7 engines, and 3-21/32" for the C-9 motors.

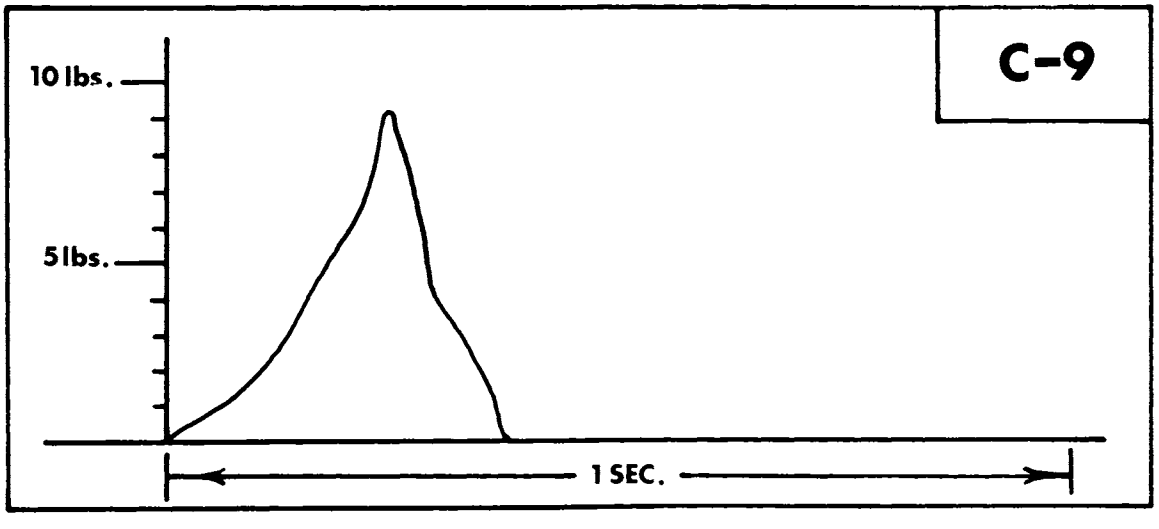
Follow the instructions in the main text. Work methodically and carefully, and WATCH OUT FOR STATIC ELECTRICITY. Follow indicated safety precautions, and do all the loading and tamping behind a properly constructed explosion shield.

The table below will list the tools required for each engine, and the numbers in the table refer to the actual drawing numbers in the pages that follow. If you are confused about any of the illustrations, we suggest that you show this section of the book to a qualified machinist, so that he can interpret the data for you.

MOTOR	A-3 BOOSTER	A-3 SINGLE	B-7 BOOSTER	B-7 SINGLE	C-9 BOOSTER	C-9 SINGLE
CASING RETAINER	02-84-001	02-84-001	02-84-001	02-84-001	02-84-002	02-84-002
RAMROD	02-84-003	02-84-003	02-84-004	02-84-004	02-84-005	02-84-005
NOZZLE TRIMMER	02-84-006	02-84-006	02-84-006	02-84-006	02-84-006	02-84-006
TAMPS	02-84-007	02-84-007	02-84-007 02-84-008	02-84-007 02-84-008	02-84-007 02-84-008	02-84-007 02-84-008
NOZZLE FORMER	02-84-009	02-84-009	02-84-010	02-84-010	02-84-011	02-84-011
CORING PINTLE	02-84-012	02-84-012	02-84-013	02-84-013	02-84-014	02-84-014
DIMPLING TOOL	02-84-015		02-84-015		02-84-015	


A-3
10 lbs.
5 lbs.
1 SEC.

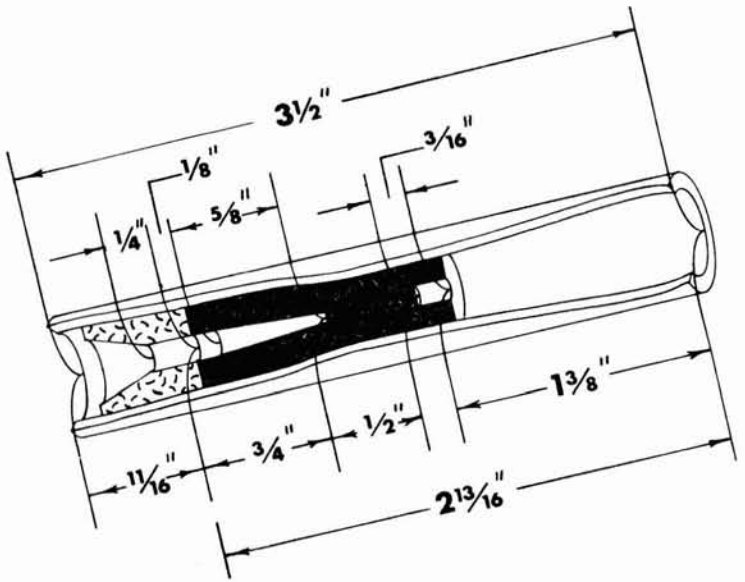

B-7
10 lbs.
5 lbs.
1 SEC.


C-9
10 lbs.
5 lbs.
1 SEC.

TELEFLITE CORPORATION

FUNCTION: **A-3 BOOSTER**

PROPELLANT WT.: 1/4 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1/2 INCH	TOTAL IMPULSE: 2.4 NT.-SECS.
NOZZLE DIA.: 5/32 INCH	PEAK THRUST: 15.6 NTS. (3.5 LBS.)
CORE LENGTH: 3/4 INCH	AVERAGE THRUST: 3.3 NTS. (12 OZ.)

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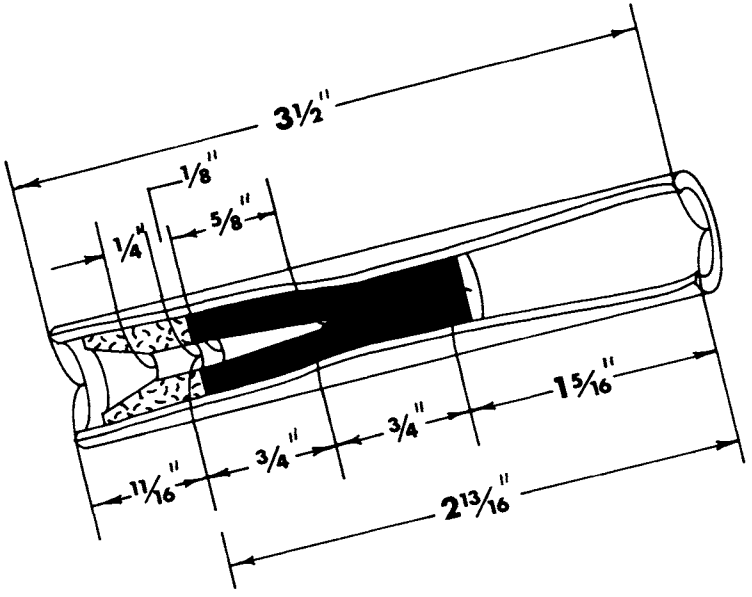
TELEFLITE CORPORATION

FUNCTION: **A-3 SINGLE STAGE**

PROPELLANT WT.: 1/4 OZ. APPROX.

TIME DELAY: 3 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1/2 INCH	TOTAL IMPULSE: 2.4 NT.-SECS.
NOZZLE DIA.: 5/32 INCH	PEAK THRUST: 15.6 NTS. (3.5 LBS.)
CORE LENGTH: 3/4 INCH	AVERAGE THRUST: 3.3 NTS. (12 OZ.)

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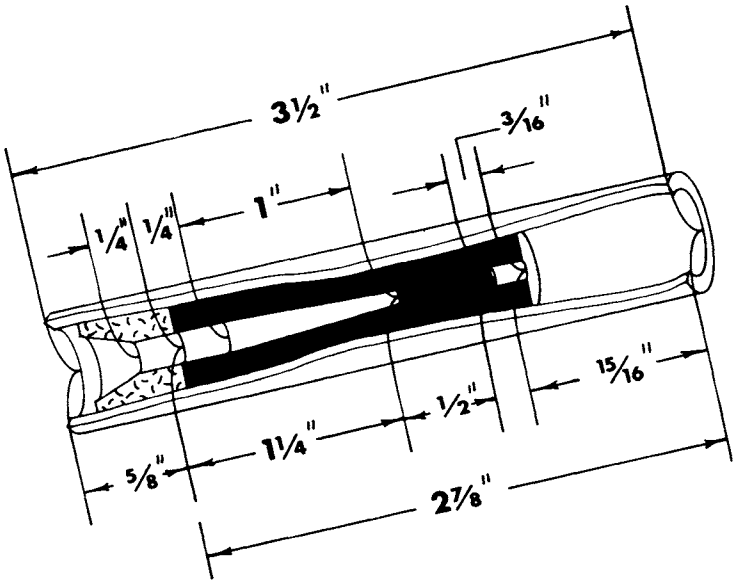
TELEFLITE CORPORATION

FUNCTION: **B-7 BOOSTER**

PROPELLANT WT.: 3/8 OZ. APPROX.

TIME DELAY:



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1/2 INCH	TOTAL IMPULSE: 4.3 NT.-SECS.
NOZZLE DIA.: 3/16 INCH	PEAK THRUST: 22 NTS. (5 LBS.)
CORE LENGTH: 1 1/4 INCH	AVERAGE THRUST: 6.7 NTS. (1 1/2 LBS.)

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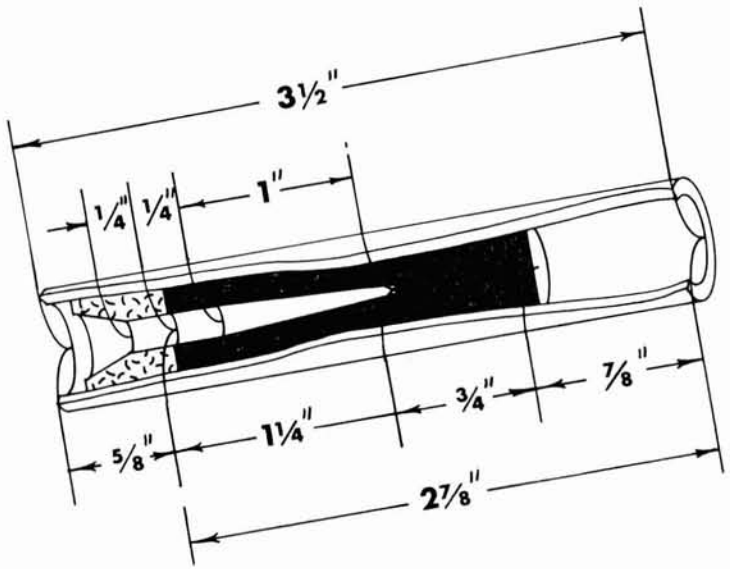
TELEFLITE CORPORATION

FUNCTION: **B-7 SINGLE STAGE**

PROPELLANT WT.: 3/8 OZ. APPROX.

TIME DELAY: 3 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1/2 INCH	TOTAL IMPULSE: 4.3 NT.-SECS.
NOZZLE DIA.: 3/16 INCH	PEAK THRUST: 22 NTS. (5 LBS.)
CORE LENGTH: 1 1/4 INCH	AVERAGE THRUST: 6.7 NTS. (1 1/2 LBS.)

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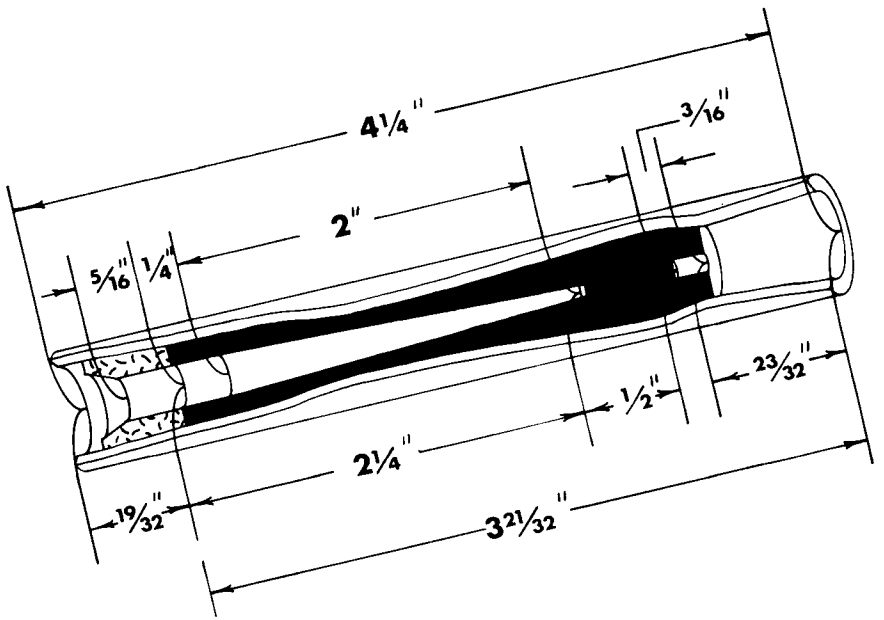
TELEFLITE CORPORATION

FUNCTION: **C-9 BOOSTER**

PROPELLANT WT.: 1/2 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1/2 INCH	TOTAL IMPULSE: 5.7 NT.-SECS.
NOZZLE DIA.: 1/4 INCH	PEAK THRUST: 40 NTS. (9 LBS.)
CORE LENGTH: 2 1/4 INCHES	AVERAGE THRUST: 8.9 NTS. (2 LBS.)

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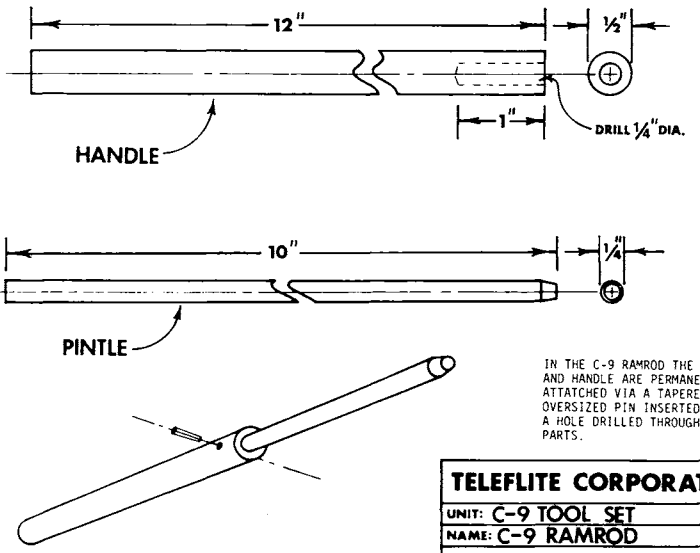

IN THE C-9 RAMROD THE PINTLE AND HANDLE ARE PERMANENTLY ATTATCHED VIA A TAPERED OR OVERSIZED PIN INSERTED INTO A HOLE DRILLED THROUGH BOTH PARTS.

TELEFLITE CORPORATION	
UNIT: C-9 TOOL SET	
NAME: C-9 RAMROD	
SHEET 1 of 1	02-84-005
SCALE: 1/2	

MATERIAL: STEEL

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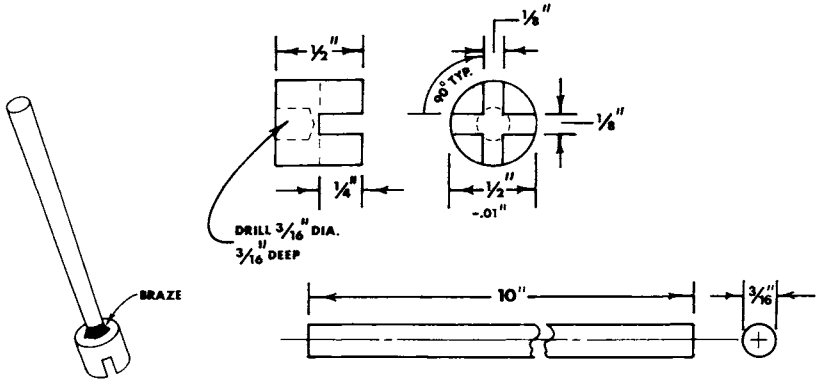

THE SHAFT OF THE NOZZLE TRIMMER SHOULD BE INSERTED INTO THE HOLE DRILLED INTO THE TRIMMER HEAD AND BRAZED INTO PLACE.

TELEFLITE CORPORATION	
UNIT: A-3 thru C-9 TOOL SET	
NAME: 1/2 INCH CASING NOZZLE TRIMMER	
SHEET 1 of 1	02-84-006
SCALE: 1:1	

MATERIAL: STEEL

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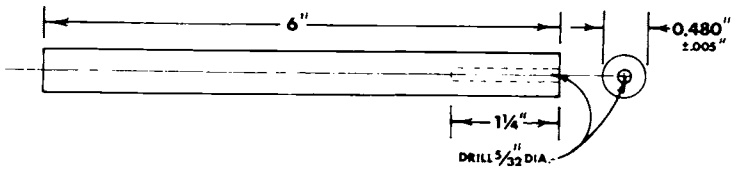

TELEFLITE CORPORATION	
UNIT: A-3 thru C-9 TOOL SET	
NAME: 5/32" X 1/2" CORED AND FLAT TAMP	
SHEET 1 of 1	02-84-007
SCALE: 1/2	

MATERIAL: NYLON

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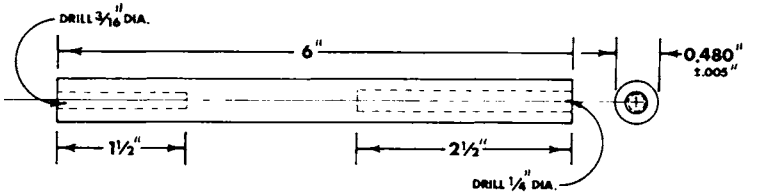

TELEFLITE CORPORATION	
UNIT: A-3 thru C-9 TOOL SET	
NAME: 1/4" X 3/16" X 1/2" CORED TAMP	
SHEET 1 of 1	02-84-008
SCALE: 1/2	

MATERIAL: NYLON

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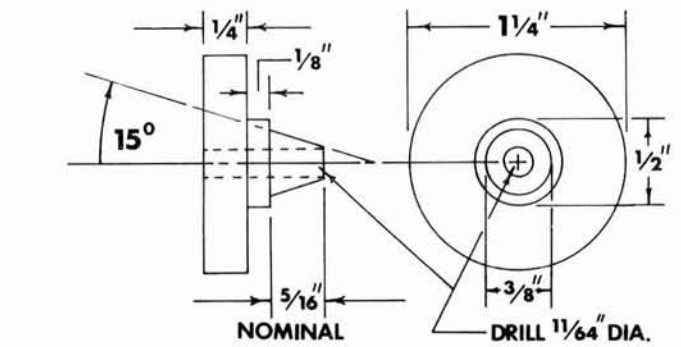

MATERIAL: STEEL

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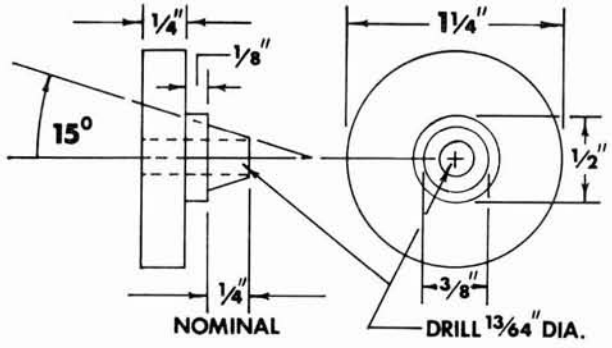
TELEFLITE CORPORATION

UNIT: A-3 TOOL SET

NAME: A-3 NOZZLE FORMER

SHEET 1 of 1 | SCALE: 1:1 | 02-84-009



MATERIAL: STEEL

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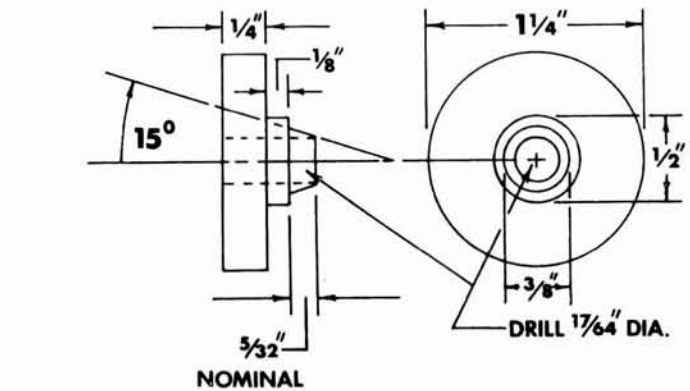
TELEFLITE CORPORATION

UNIT: B-7 TOOL SET

NAME: B-7 NOZZLE FORMER

SHEET 1 of 1 | SCALE: 1:1 | 02-84-010



MATERIAL: STEEL

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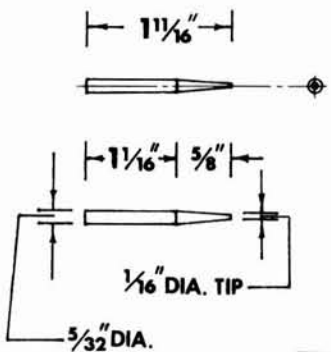
TELEFLITE CORPORATION

UNIT: C-9 TOOL SET

NAME: C-9 NOZZLE FORMER

SHEET 1 of 1 | SCALE: 1:1 | 02-84-011



MATERIAL: BRASS

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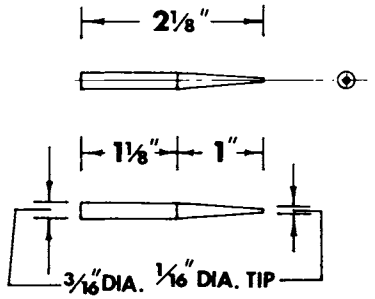
TELEFLITE CORPORATION

UNIT: A-3 TOOL SET

NAME: A-3 CORING PINTLE

SHEET 1 of 1 | SCALE: 1:2 | 02-84-012



TELEFLITE CORPORATION

UNIT: B-7 TOOL SET

NAME: B-7 CORING PINTLE

SHEET 1 of 1

SCALE: 1:2

02-84-013

MATERIAL: BRASS

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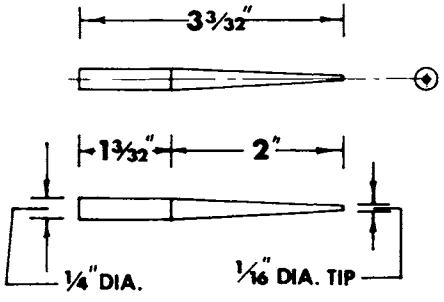

TELEFLITE CORPORATION

UNIT: C-9 TOOL SET

NAME: C-9 CORING PINTLE

SHEET 1 of 1

SCALE: 1:2

02-84-014

MATERIAL: BRASS

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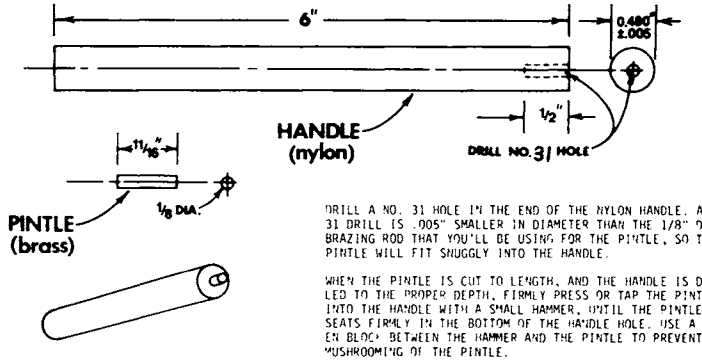

DRILL A NO. 31 HOLE IN THE END OF THE NYLON HANDLE. A NO. 31 DRILL IS .005" SMALLER IN DIAMETER THAN THE 1/8" DIA. BRAZING ROD THAT YOU'LL BE USING FOR THE PINTLE, SO THE PINTLE WILL FIT SNUGGLY INTO THE HANDLE.

WHEN THE PINTLE IS CUT TO LENGTH, AND THE HANDLE IS DRILLED TO THE PROPER DEPTH, FIRMLY PRESS OR TAP THE PINTLE INTO THE HANDLE WITH A SMALL HAMMER, UNTIL THE PINTLE SEATS FIRMLY IN THE BOTTOM OF THE HANDLE HOLE. USE A WOODEN BLOCK BETWEEN THE HAMMER AND THE PINTLE TO PREVENT MUSHROOMING OF THE PINTLE.

TELEFLITE CORPORATION

UNIT: A-3 thru C-9 TOOL SET

NAME: DIMPLING TOOL

SHEET 1 of 1

SCALE: 1/2

02-84-015

MATERIALS: NYLON and BRASS

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FORWARD BULKHEAD CONSTRUCTION

When building the small, 1/2" cased A, B, and C engines, there is no need to build in a forward bulkhead. A property called "bridge strength" gives the cured propellant plugs in the fronts of these motors enough toughness to allow them to function as forward bulkheads in and of themselves.

This is NOT the case, however, when building larger engines. In motors of larger inside diameter the bridge strength of hand-tamped gunpowder is not sufficient to withstand engine operating pressures. This is not a universal condition in the 3/4" I.D. engines, but we advise the construction of a bulkhead anyway, as we've discovered that without the bulkhead, about one out of ten of these motors will "blow its nose" before achieving maximum thrust.

The addition of a bulkhead requires a few extra steps in engine construction and some extra tooling, and in the following pages you'll find a series of pen and ink illustrations depicting the additional needed operations.

Follow all the building instructions in the main text (including the addition of wax described in the appendices) up through FIGURE 20 on page 38. At this point refer to FIGURE 40 in this supplement and adopt the following procedure.

Insert the FORWARD BULKHEAD PINTLE, the PINTLE SLEEVE, and the FORWARD BULKHEAD TAMP into the front of the engine casing (FIGURE 40), and drive the entire assembly home with four or five good, solid hammer blows (FIGURE 41). The pintle "bottoms out" in the hole drilled in the bulkhead tamp, passes through the pintle sleeve, and protrudes 3/16" into the gunpowder packed at the front of the motor.

Remove the sleeve and tamp, leaving the pintle behind, stuck in the gunpowder, and pour in a small amount of shaved candle wax (FIGURE 42). Reinsert the sleeve and tamp, tap a few light blows with the hammer, then press down and twist the assembly against the wax in the front of the casing (FIGURE 43).

Remove the sleeve and tamp once again, and pour in ONE SCOOP of dry, clay nozzle composition (FIGURE 44). Reinsert the sleeve and tamp, and using five or six SOLID hammer blows (FIGURE 45) firmly compress the clay powder into the front of the motor.

Remove the tamp itself, hold onto the sleeve so that it is not pulled from the front of the casing, and use a pair of pliers to withdraw the pintle (FIGURE 46). Once again, as in the case of the nozzle construction, the pintle should be coated with non-stick vegetable cookware coating to make withdrawal easier. This sleeve is left in position (FIGURE 47) to prevent tearing out of the clay composition during pintle withdrawal.

Now gently withdraw the sleeve (FIGURE 48), and you're done.

With the bulkhead now in place, you can use the porthole to hold a staging tube, as in the case of a booster engine, or you can fill it with a loose powder or a quick fuse to ignite a parachute delay charge in the case of an upper or single stage motor.

The bulkhead is composed of dry clay, and this will complicate your considerations when attempting to calculate the correct firing weight. You can correct the situation if you do the following. In all motors with forward bulkheads multiply the damp weight by .95 instead of .93. This will introduce a correction factor that will compensate for the extra dry material.

If you use a food dehydrator, follow the drying procedure suggested in the main text. 3/4" cased motors will take quite a bit longer to dry than the 1/2" ones, AND they will take quite a while longer to equalize once they're removed from the dehydrator.

When firing one of these motors, insert the igniters as deep as they will go WITH THE EXCEPTION OF THE E-30 MOTOR! When firing the E-30, keep the igniter close to the nozzle, or you may risk an explosion on the launch pad.

In the deeper cored motors (i.e. the E-30, G-75, and G-100 motors) you DON'T want the propellant to begin burning from the front of the engine. Inserting the igniter just deep enough to contact the powder insures that the ignition will start at the nozzle and progress forward.

If you settle on building JUST these deeper cored motors, you can correct for this by simply lowering the sulfur content of your gunpowder. Your object will be to produce a propellant of low enough impulse to allow engine ignition to start at the FRONT of the motor and proceed to the rear, just the reverse of the ignition pattern used in the shorter cored engines.

As stated in the main text, use CARE, and COMMON SENSE in everything you do. Work CAREFULLY and METHODICALLY, and discard all defective motors by soaking in water.

Be sure to follow all local, state, and federal fire and safety regulations, and be sure to consider the safety of those around you, AND their property. It is YOUR responsibility to keep a perfect safety record, and any accidents or damage inflicted on you or others by YOU will reflect badly on amateur rocketry as a whole. PLEASE BE SAFE!

FIGURE 40

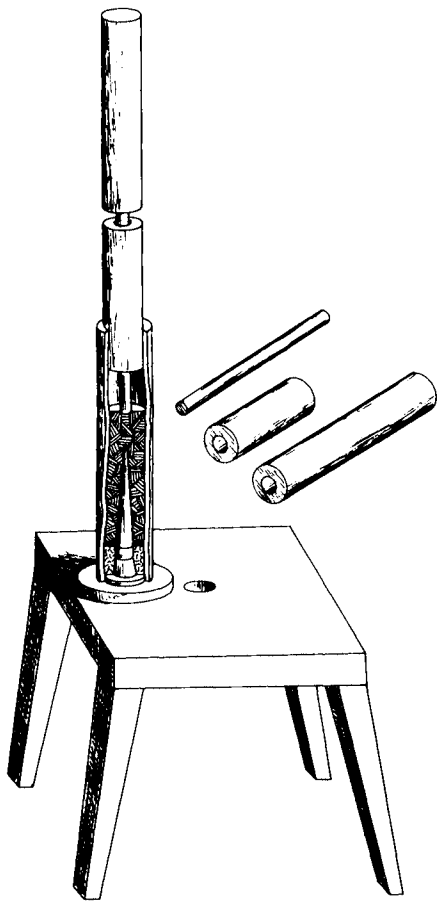


FIGURE 41

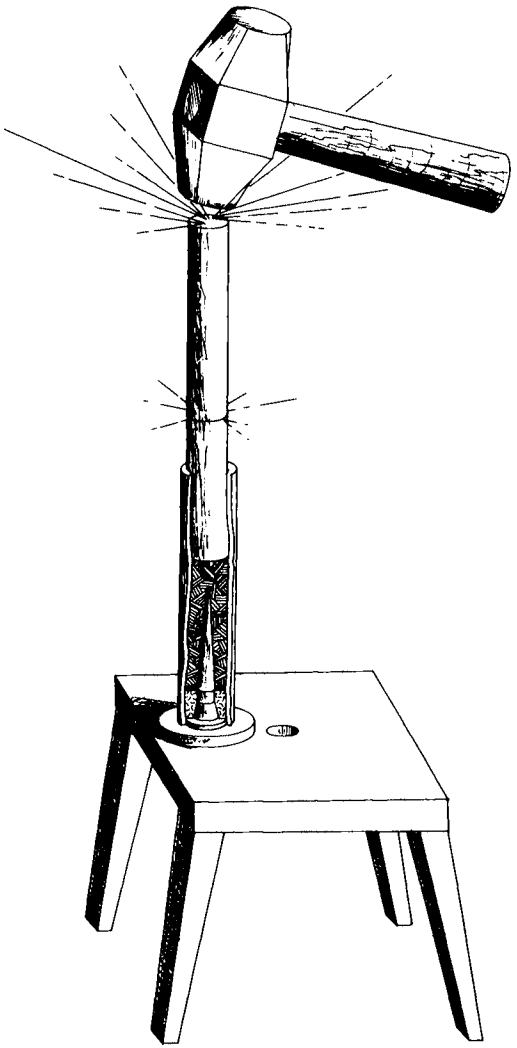


FIGURE 42

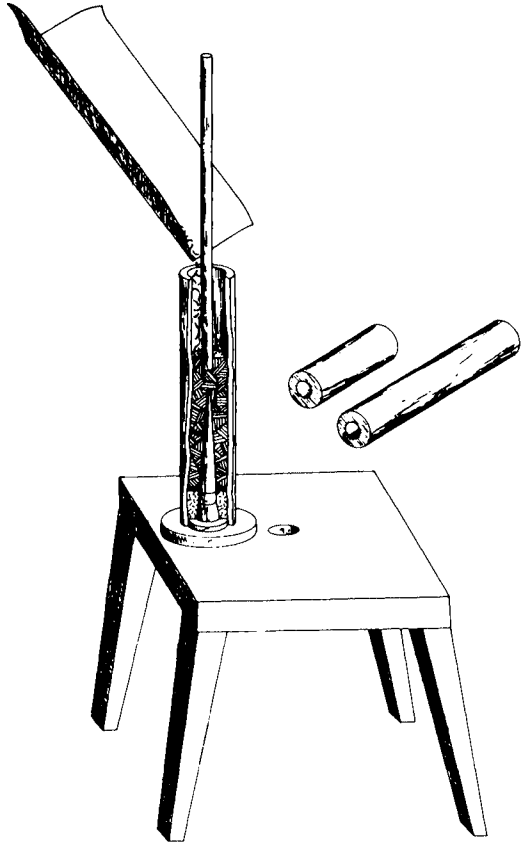


FIGURE 43

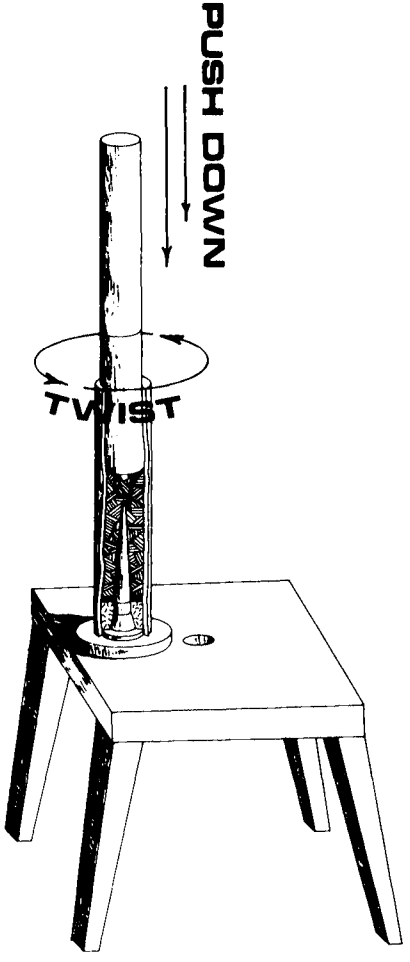


FIGURE 44

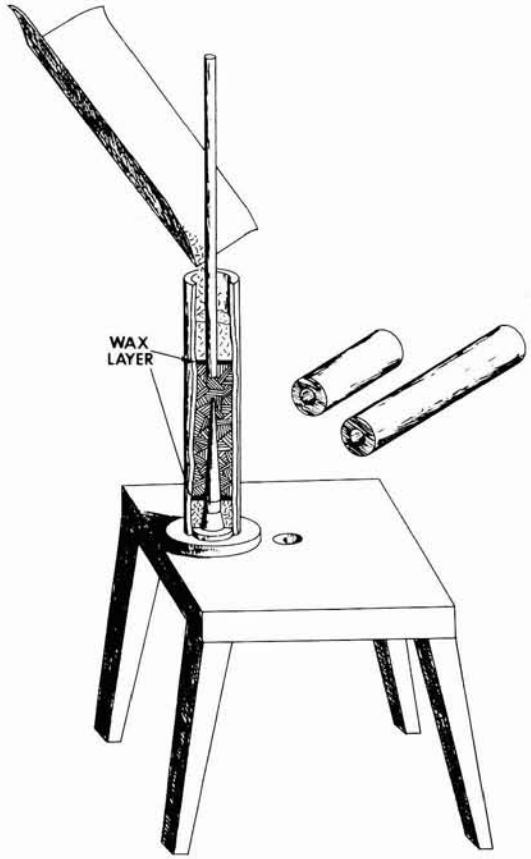


FIGURE 45

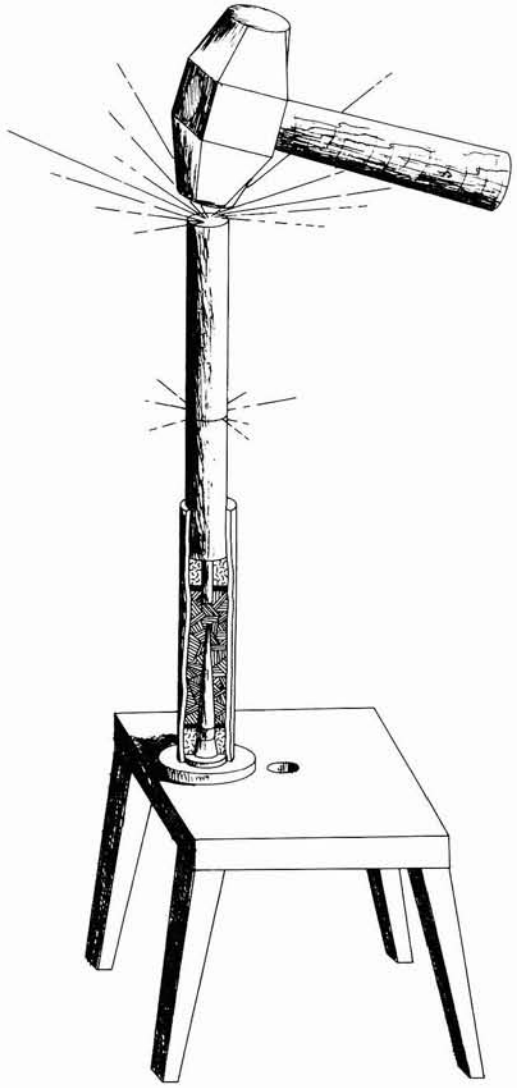


FIGURE 46

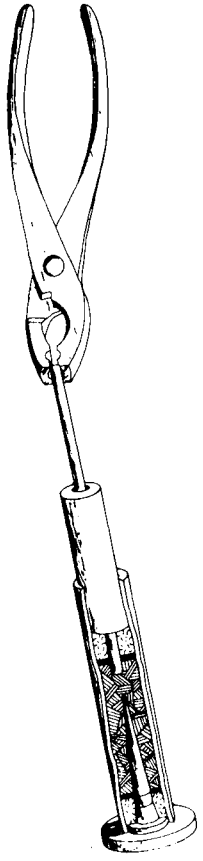


FIGURE 47

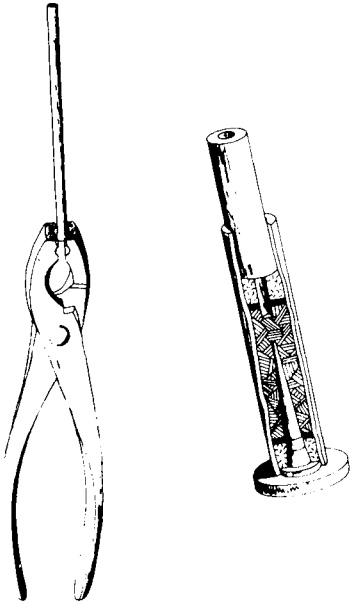
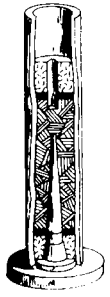


FIGURE 48



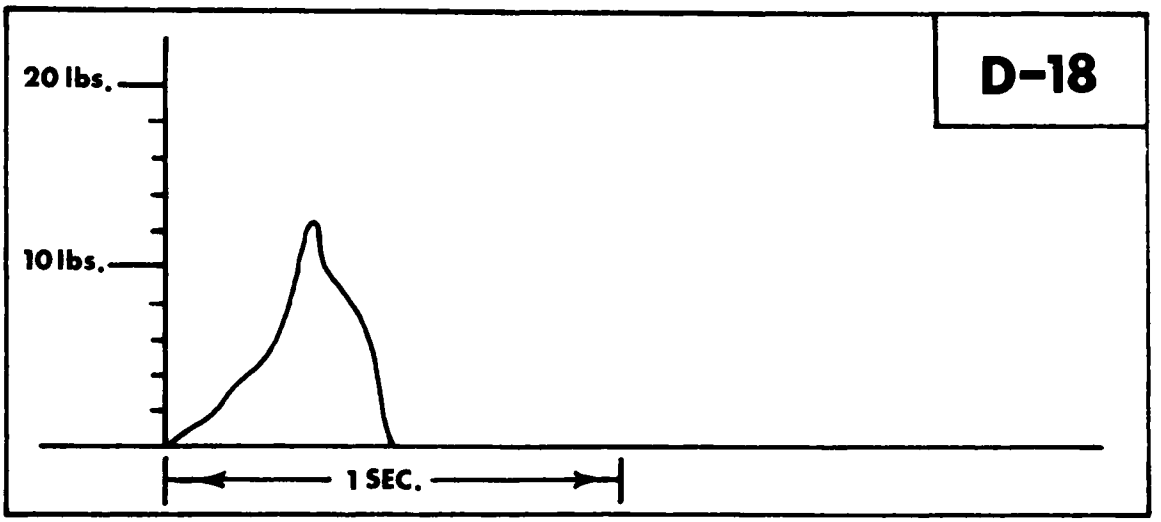
ENGINE PLANS

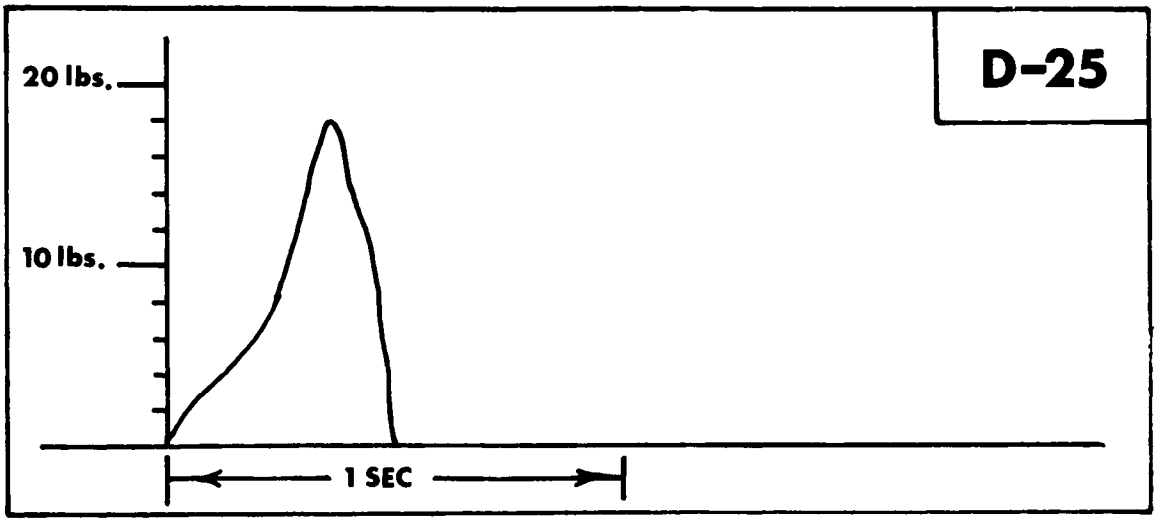
The following pages will supply you with six full-sized cutaway engine drawings, each one illustrating all the critical measurements to be followed in its construction. Engine sizes are D-18, D-25, and E-30, and there are both booster and single (or upper) stage versions of each.

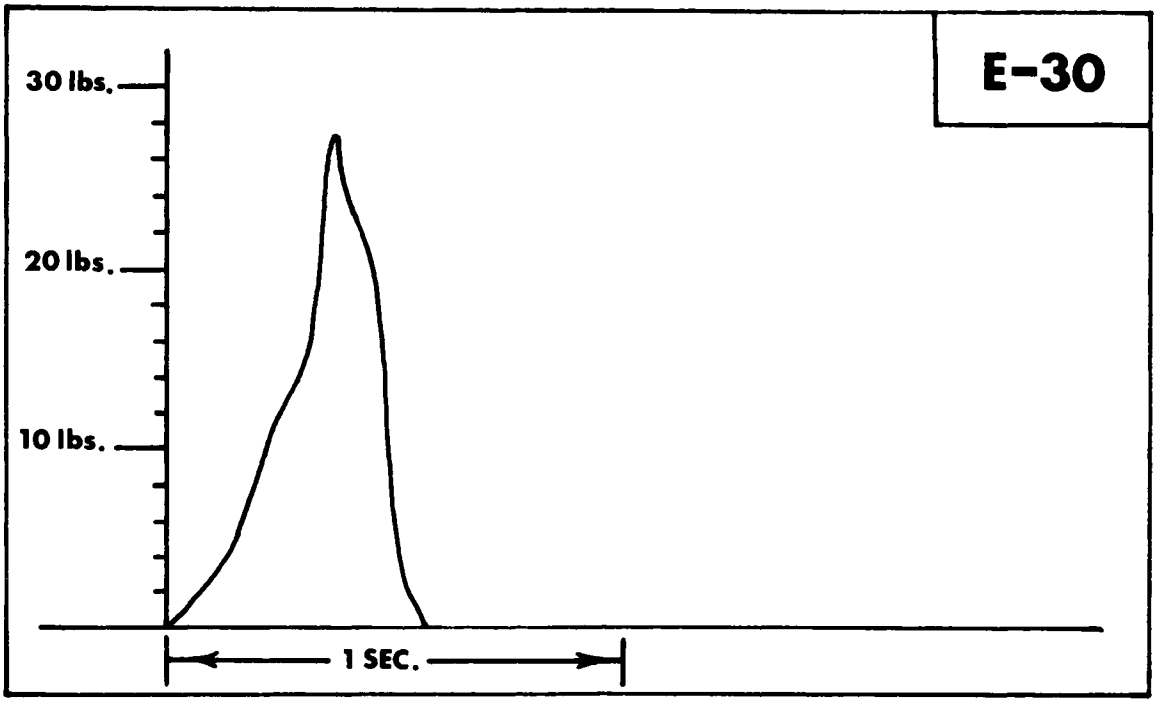
Set nozzle trimmer depths as follows: 3-3/8" for the D-18 booster, 3-7/8" for the D-18 single stage, 5" for all D-25 engines, and 6" for all E-30 motors.

The table below will list the tools reqired for each engine, and the numbers in the table refer to the actual drawing numbers in the pages that follow.

MOTOR	D-18 BOOSTER	D-18 SINGLE	D-25 BOOSTER	D-25 SINGLE	E-30 BOOSTER	E-30 SINGLE
CASING RETAINER	02-84-016	02-84-017	02-84-018	02-84-018	02-84-019	02-84-019
RAMROD	02-84-020	02-84-020	02-84-021	02-84-021	02-84-022	02-84-022
NOZZLE TRIMMER	02-84-023	02-84-023	02-84-023	02-84-023	02-84-023	02-84-023
TAMPS	02-84-024 02-84-025	02-84-024 02-84-025	02-84-024 02-84-025	02-84-024 02-84-025	02-84-024 02-84-025	02-84-024 02-84-025
NOZZLE FORMER	02-84-026	02-84-026	02-84-027	02-84-027	02-84-028	02-84-028
CORING PINTLE	02-84-029	02-84-029	02-84-030	02-84-030	02-84-031	02-84-031
BULKHEAD PINTLE	02-84-032	02-84-032	02-84-032	02-84-032	02-84-032	02-84-032
PINTLE SLEEVE	02-84-033	02-84-033	02-84-033	02-84-033	02-84-033	02-84-033
BULKHEAD TAMP	02-84-034	02-84-034	02-84-034	02-84-034	02-84-034	02-84-034


D-18
20 lbs.
10 lbs.
1 SEC.

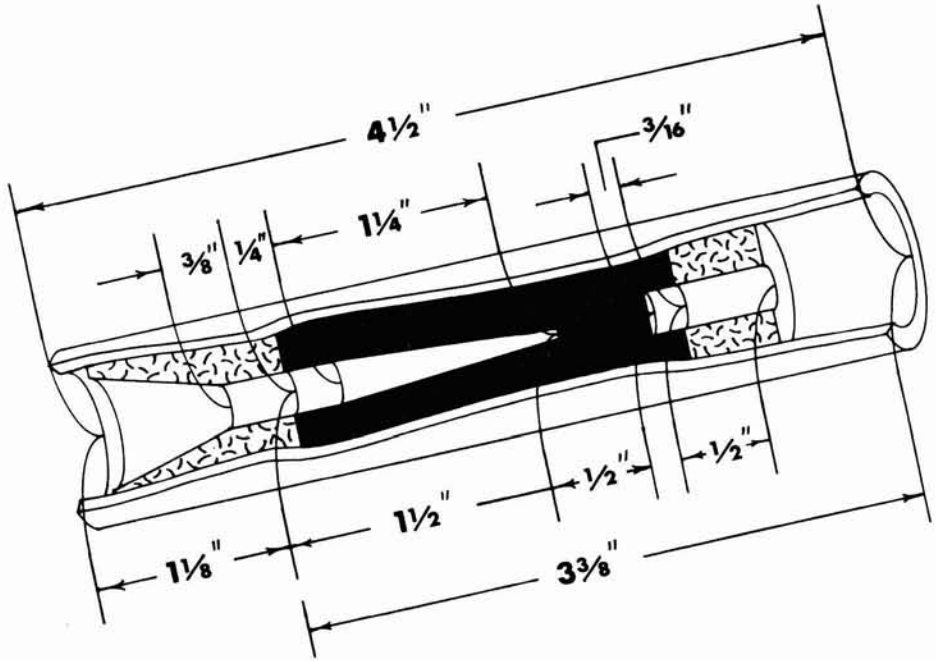

D-25
20 lbs.
10 lbs.
1 SEC


E-30
30 lbs.
20 lbs.
10 lbs.
1 SEC.

TELEFLITE CORPORATION

FUNCTION: **D-18 BOOSTER**

PROPELLANT WT.: 1OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 11.7 NT.-SECS.
NOZZLE DIA.: 1/4 INCH	PEAK THRUST: 54.5 NTS. (12.25 LBS.)
CORE LENGTH: 1 1/2 INCHES	AVERAGE THRUST: 17.3 NTS. (3.9 LBS.)

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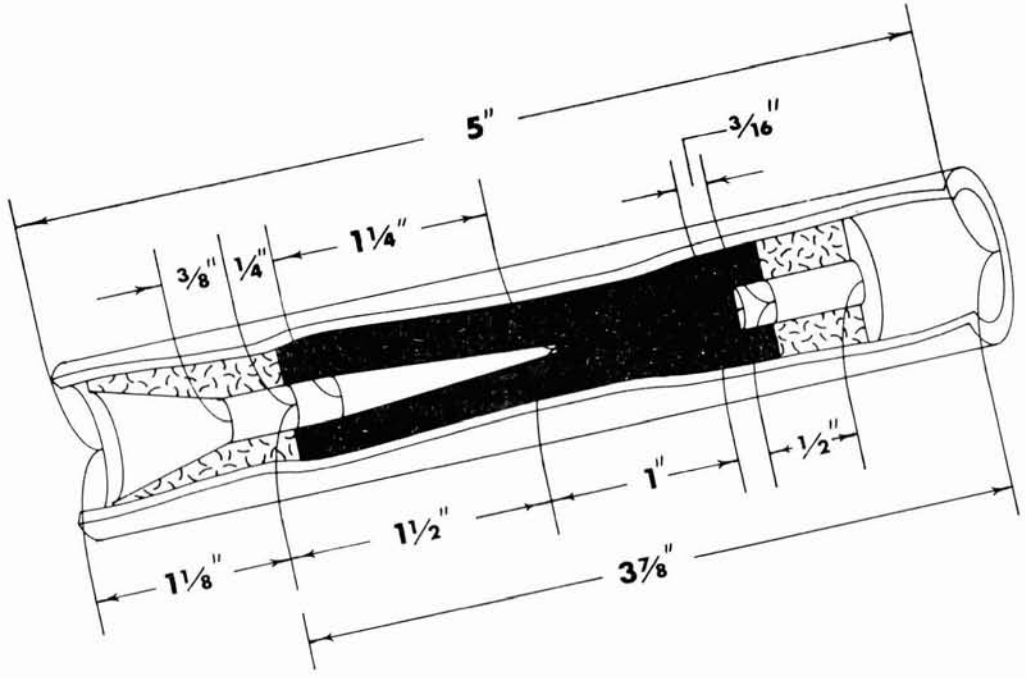
TELEFLITE CORPORATION

FUNCTION: **D-18 SINGLE STAGE**

PROPELLANT WT.: 1 OZ. APPROX.

TIME DELAY: 4 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 11.7 NT.-SECS.
NOZZLE DIA.: 1/4 INCH	PEAK THRUST: 54.5 NTS. (12.25 LBS.)
CORE LENGTH: 1 1/2 INCHES	AVERAGE THRUST: 17.3 NTS. (3.9 LBS.)

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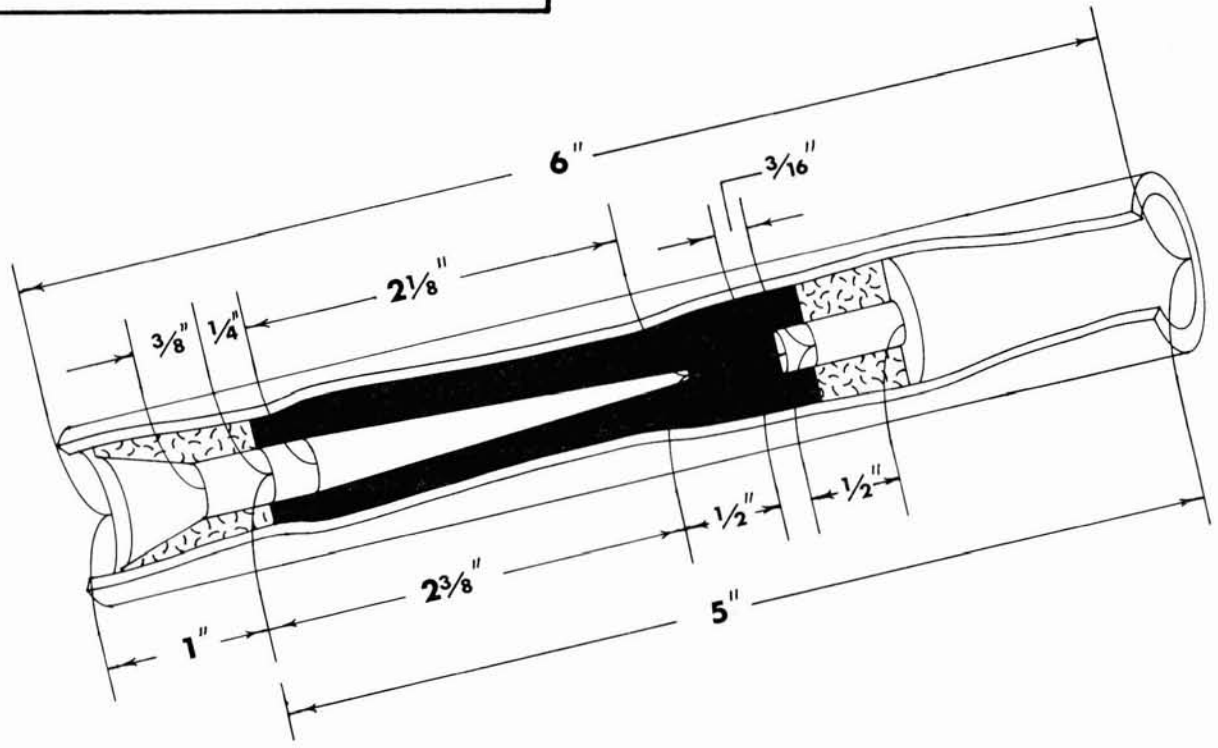
TELEFLITE CORPORATION

FUNCTION: **D-25 BOOSTER**

PROPELLANT WT.: 1 1/2 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 18.5 NT.-SECS.
NOZZLE DIA.: 5/16 INCH	PEAK THRUST: 80 NTS. (18 LBS.)
CORE LENGTH: 2 3/8 INCHES	AVERAGE THRUST: 22 NTS. (5 LBS.)

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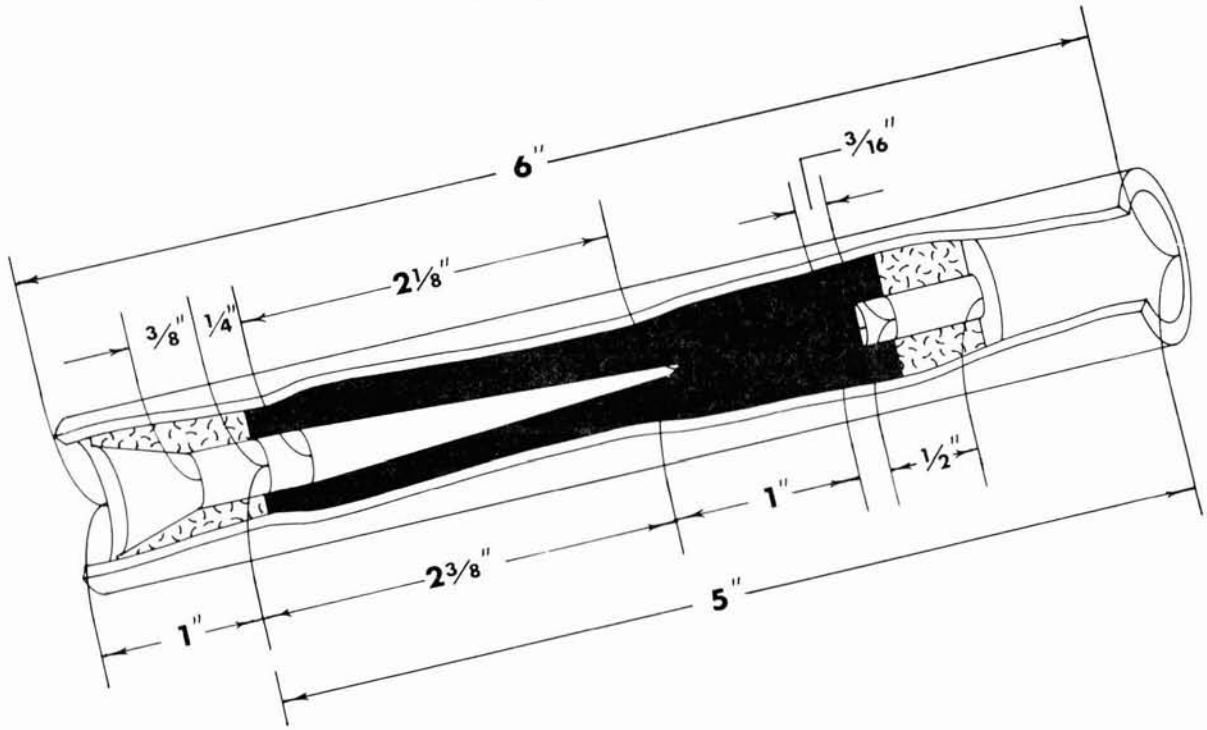
TELEFLITE CORPORATION

FUNCTION: **D-25 SINGLE STAGE**

PROPELLANT WT.: 1 1/2 OZ. APPROX.

TIME DELAY: 4 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 18.5 NT.-SECS.
NOZZLE DIA.: 5/16 INCH	PEAK THRUST: 80 NTS. (18 LBS.)
CORE LENGTH: 2 3/8 INCHES	AVERAGE THRUST: 22 NTS. (5 LBS.)

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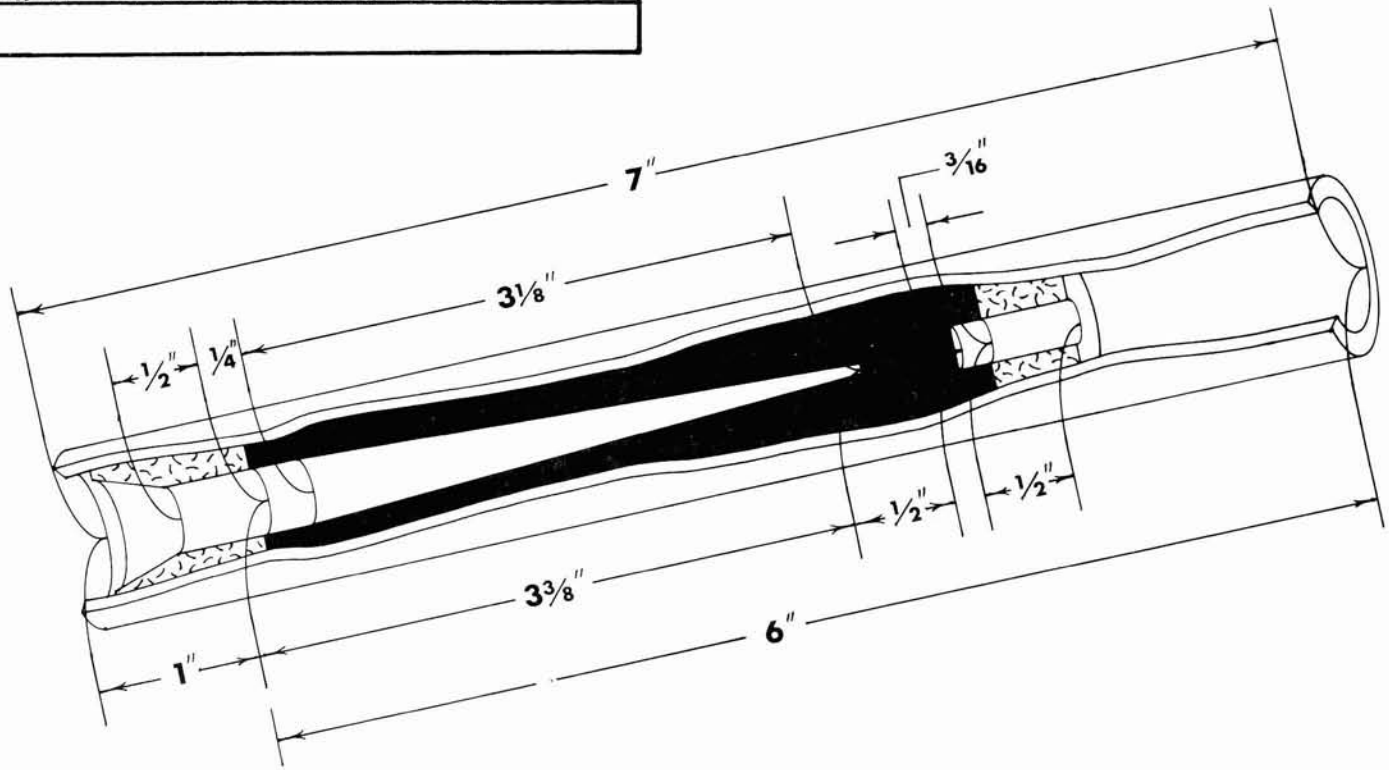
TELEFLITE CORPORATION

FUNCTION: **E-30 BOOSTER**

PROPELLANT WT.: 2 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 26 NT.-SECS.
NOZZLE DIA.: 3/8 INCH	PEAK THRUST: 120 NTS. (27 LBS.)
CORE LENGTH: 3 3/8 INCHES	AVERAGE THRUST: 31 NTS. (7 LBS.)

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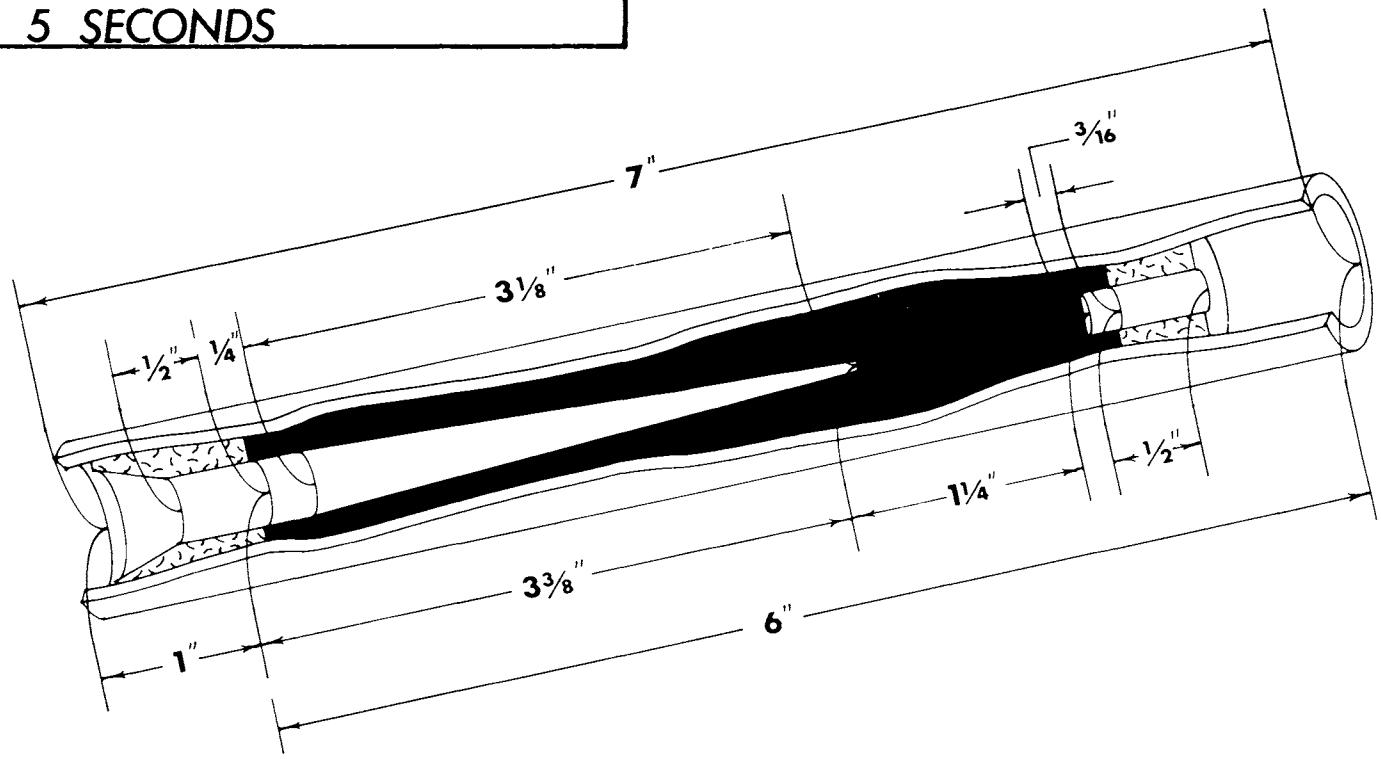
TELEFLITE CORPORATION

FUNCTION: **E-30 SINGLE STAGE**

PROPELLANT WT.: 2 OZ. APPROX.

TIME DELAY: 5 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 3/4 INCH	TOTAL IMPULSE: 26 NT.-SECS.
NOZZLE DIA.: 3/8 INCH	PEAK THRUST: 120 NTS. (27 LBS.)
CORE LENGTH: 3 3/8 INCHES	AVERAGE THRUST: 31 NTS. (7 LBS.)

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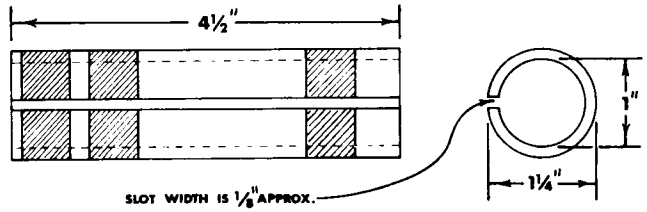
ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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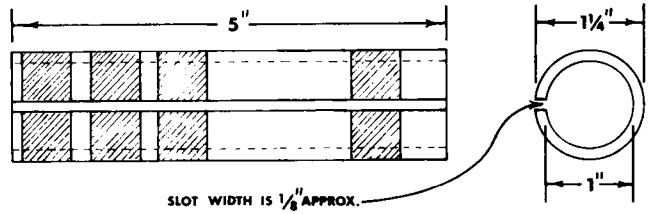
TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: CASING RETAINER FOR D-18 BOOSTER
SHEET 1 of 1
SCALE: 1/2

02-84-016

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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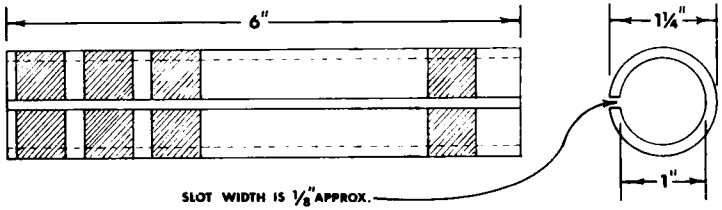
TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: CASING RETAINER FOR D-18 SINGLE STAGE ENGINE
SHEET 1 of 1
SCALE: 1/2

02-84-017

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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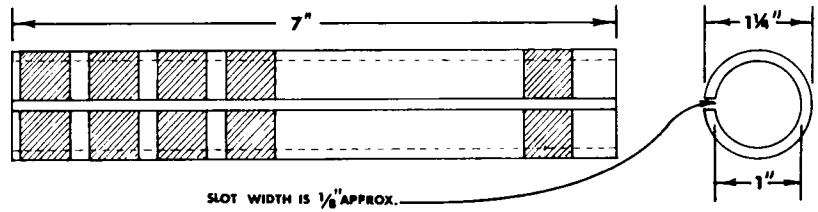
TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: CASING RETAINER FOR D-25 ENGINES
SHEET 1 of 1
SCALE: 1/2

02-84-018

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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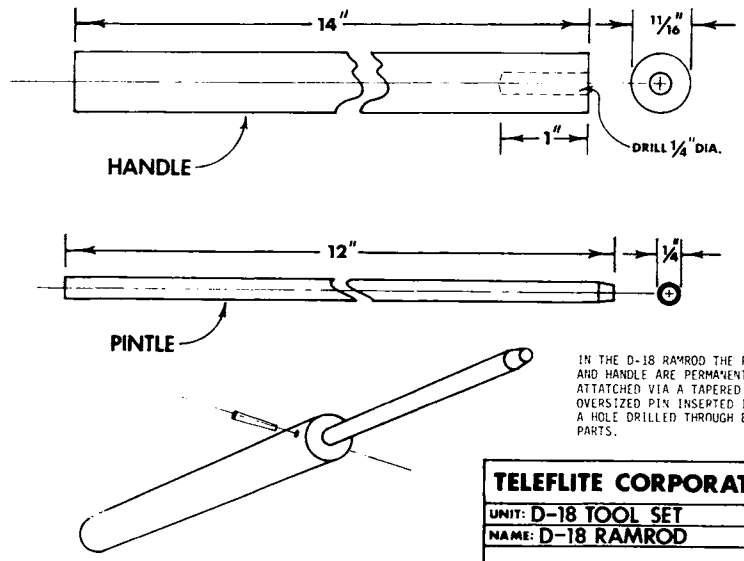
TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: CASING RETAINER FOR E-30 ENGINES
SHEET 1 of 1
SCALE: 1/2

02-84-019



IN THE D-18 RAMROD THE PINTLE AND HANDLE ARE PERMANENTLY ATTATCHED VIA A TAPERED OR OVERSIZED PIN INSERTED INTO A HOLE DRILLED THROUGH BOTH PARTS.

TELEFLITE CORPORATION

UNIT: D-18 TOOL SET
NAME: D-18 RAMROD
SHEET 1 of 1
SCALE: 1/2
02-84-020

MATERIAL: STEEL

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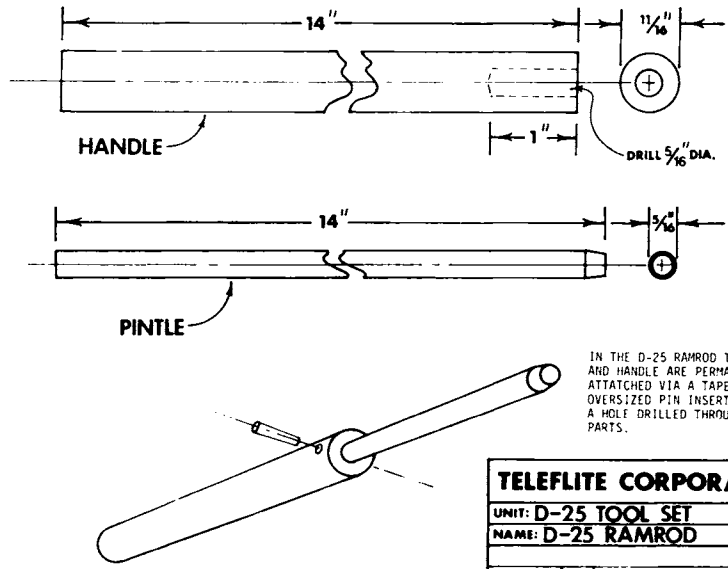

IN THE D-25 RAMROD THE PINTLE AND HANDLE ARE PERMANENTLY ATTATCHED VIA A TAPERED OR OVERSIZED PIN INSERTED INTO A HOLE DRILLED THROUGH BOTH PARTS.

TELEFLITE CORPORATION

UNIT: D-25 TOOL SET
NAME: D-25 RAMROD
SHEET 1 of 1
SCALE: 1/2
02-84-021

MATERIAL: STEEL

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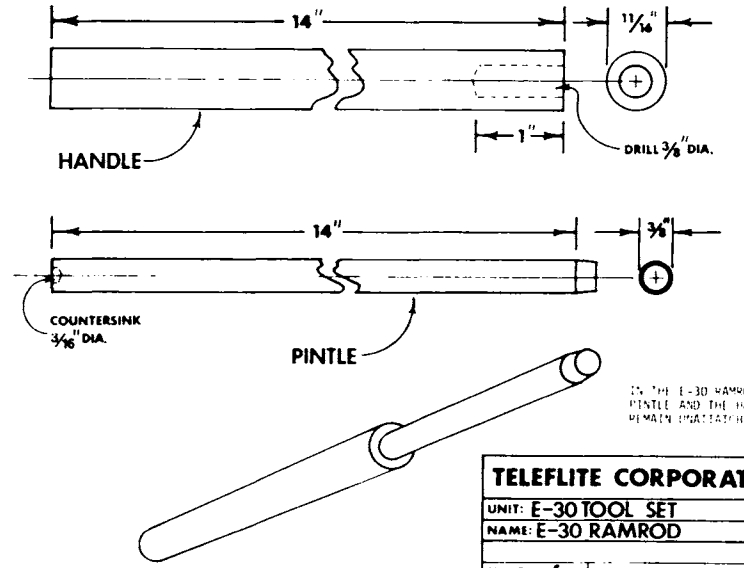

IN THE E-30 RAMROD THE PINTLE AND THE HANDLE REMAIN UNATTACHED.

TELEFLITE CORPORATION

UNIT: E-30 TOOL SET
NAME: E-30 RAMROD
SHEET 1 of 1
SCALE: 1/2
02-84-022

MATERIAL: STEEL

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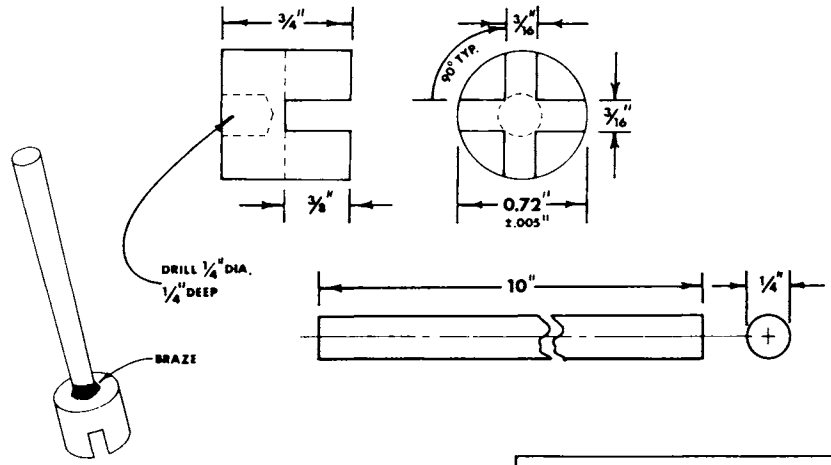

THE SHAFT OF THE NOZZLE TRIMMER SHOULD BE INSERTED INTO THE HOLE DRILLED INTO THE TRIMMER HEAD AND BRAZED INTO PLACE.

TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: 3/4 INCH CASING NOZZLE TRIMMER
SHEET 1 of 1
SCALE: 1:1
02-84-023

MATERIAL: STEEL

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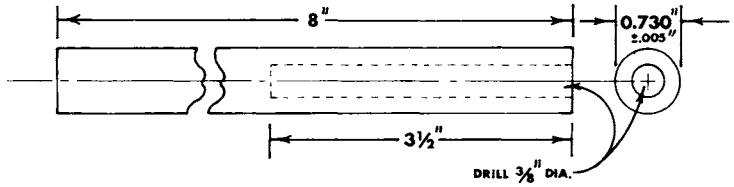

TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: 3/8" X 3/4" CORED AND FLAT TAMP
SHEET 1 of 1
SCALE: 1/2

02-84-024

MATERIAL: **NYLON**

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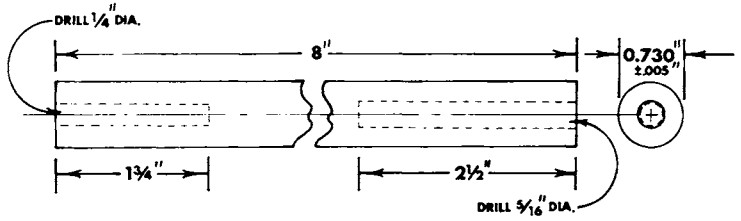

TELEFLITE CORPORATION

UNIT: D-18 thru E-30 TOOL SET
NAME: 5/16" X 1/4" X 3/4" CORED TAMP
SHEET 1 of 1
SCALE: 1/2

02-84-025

MATERIAL: **NYLON**

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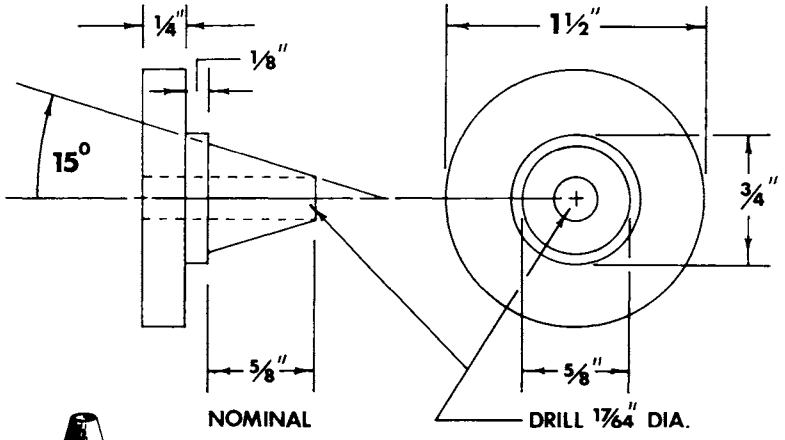

TELEFLITE CORPORATION

UNIT: D-18 TOOL SET
NAME: D-18 NOZZLE FORMER
SHEET 1 of 1
SCALE: 1:1

02-84-026

MATERIAL: **STEEL**

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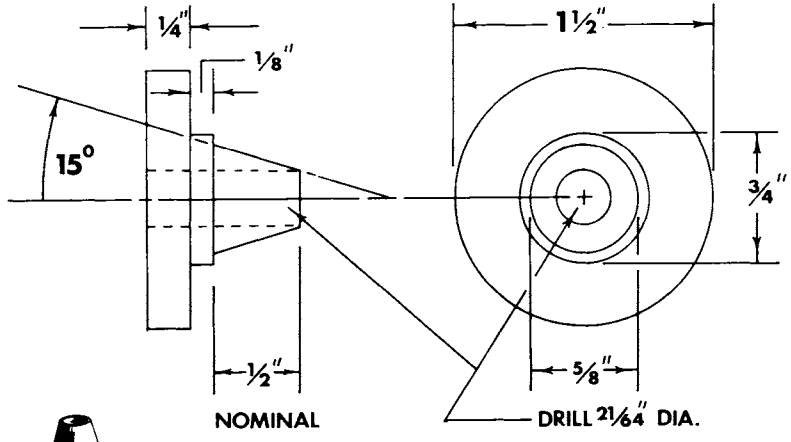

TELEFLITE CORPORATION

UNIT: D-25 TOOL SET
NAME: D-25 NOZZLE FORMER
SHEET 1 of 1
SCALE: 1:1

02-84-027

MATERIAL: **STEEL**

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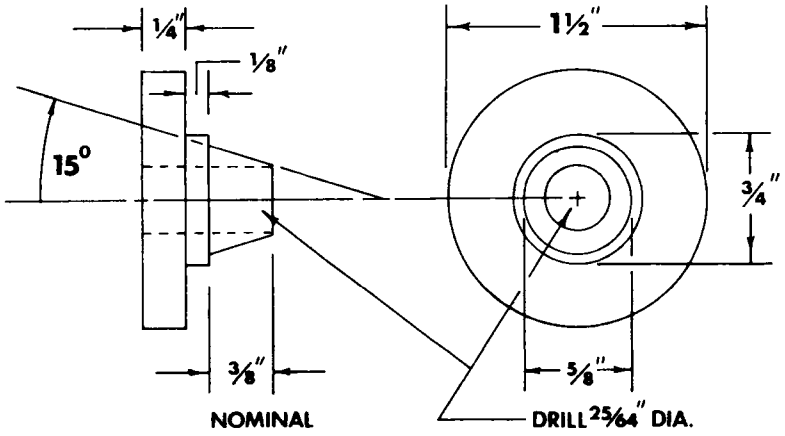

TELEFLITE CORPORATION

UNIT: E-30 TOOL SET
NAME: E-30 NOZZLE FORMER
SHEET 1 of 1
SCALE: 1:1

02-84-028

MATERIAL: STEEL

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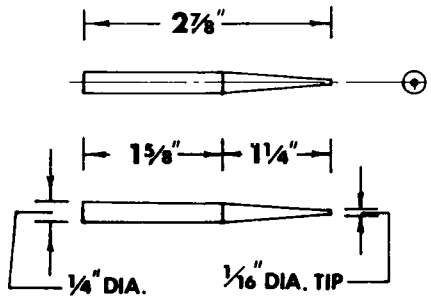


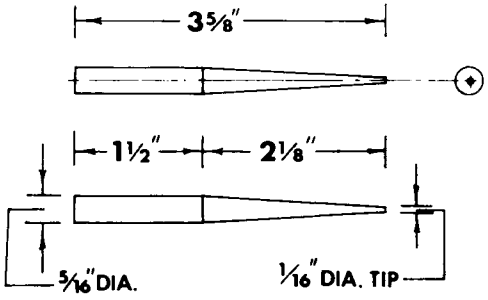
TELEFLITE CORPORATION

UNIT: D-18 TOOL SET
NAME: D-18 CORING PINTLE
SHEET 1 of 1
SCALE: 1:2

02-84-029

MATERIAL: BRASS

COPYRIGHT 1984 THE TELEFLITE CORPORATION



TELEFLITE CORPORATION

UNIT: D-25 TOOL SET
NAME: D-25 CORING PINTLE
SHEET 1 of 1
SCALE: 1:2

02-84-030

MATERIAL: BRASS

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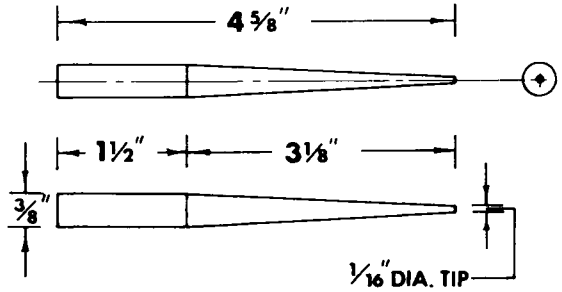

TELEFLITE CORPORATION

UNIT: E-30 TOOL SET
NAME: E-30 CORING PINTLE
SHEET 1 of 1
SCALE: 1:2

02-84-031

MATERIAL: BRASS

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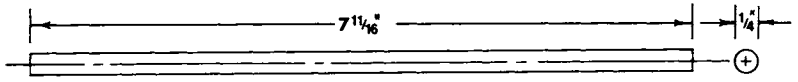

TELEFLITE CORPORATION	
UNIT: D-18 thru G-100 TOOL SET	
NAME: FORWARD BULKHEAD PINTLE	
SHEET 1 of 1	02-84-032
SCALE: 1/2	

MATERIAL: BRASS

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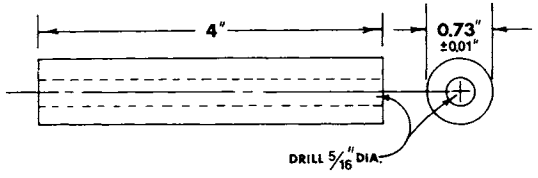

TELEFLITE CORPORATION	
UNIT: D-18 thru E-30 TOOL SET	
NAME: D-18 thru E-30 PINTLE SLEEVE	
SHEET 1 of 1	02-84-033
SCALE: 1/2	

MATERIAL: NYLON

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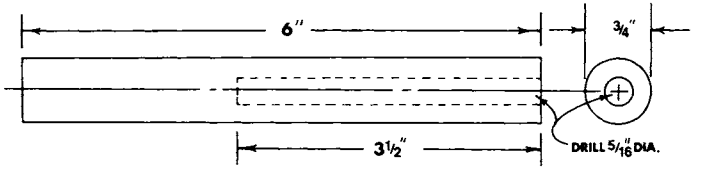

TELEFLITE CORPORATION	
UNIT: D-18 thru E-30 TOOL SET	
NAME: D-18 thru E-30 BULKHEAD TAMP	
SHEET 1 of 1	02-84-034
SCALE: 1/2	

MATERIAL: NYLON

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NOTES

ENGINE PLANS

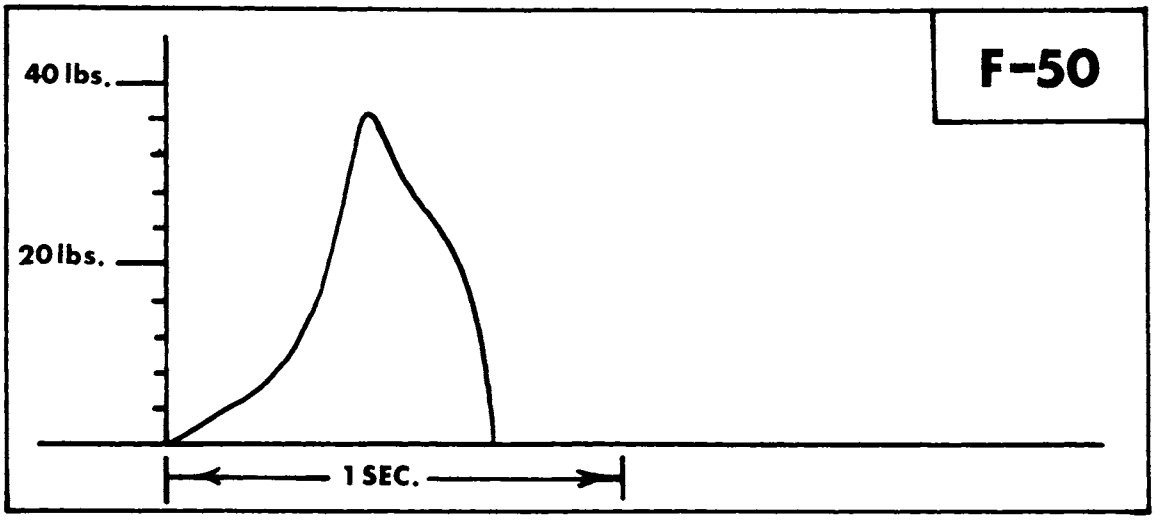
This publication is intended only as a supplement to the main text and the mid-sized casing supplement. When building these larger engines, follow all instructions in the main text including the addition of wax moisture barriers described in the main text appendices and the construction of forward bulkheads outlined in the 3/4" casing supplement.

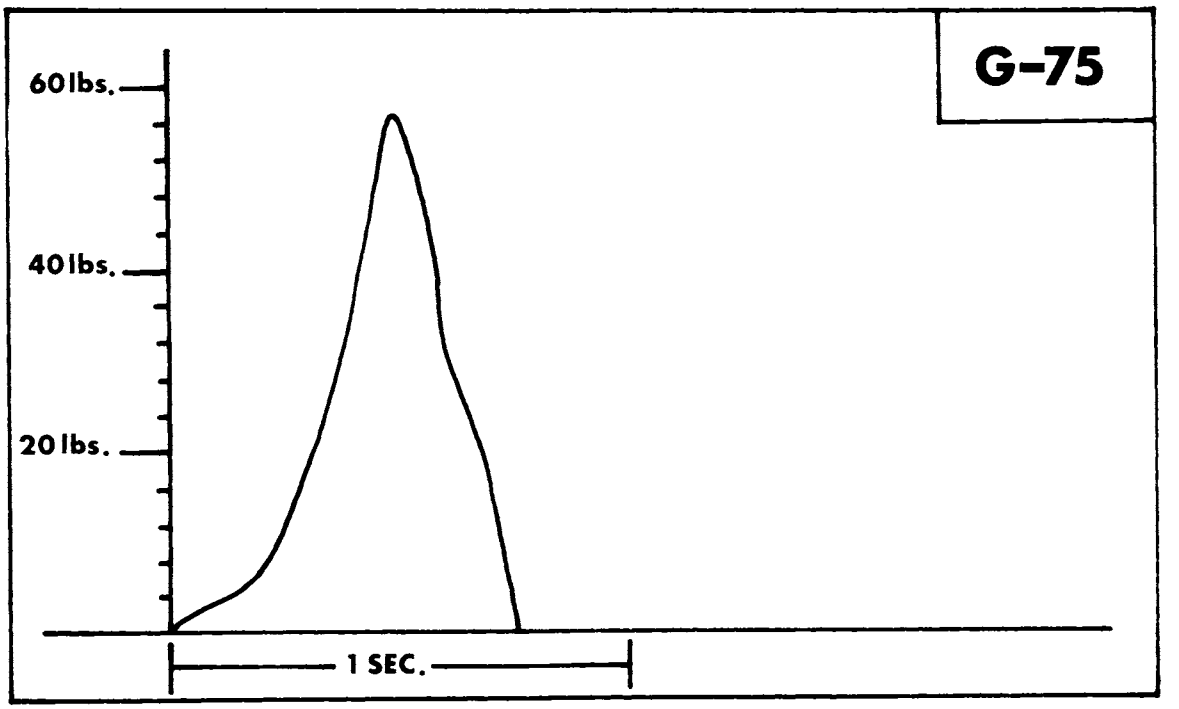
The following pages will supply you with six full-sized cutaway engine drawings, each one illustrating all the critical measurements to be followed in its construction. Engine sizes are F-50, G-75, and G-100, and there are both booster and single (or upper) stage versions of each.

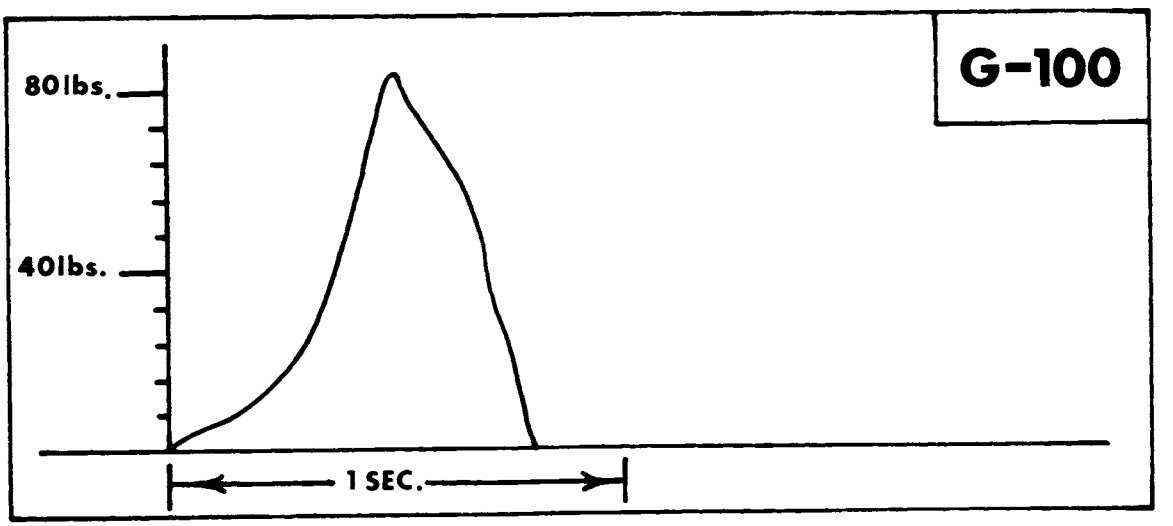
Set nozzle trimmer depths as follows: 5-7/16" for the F-50 booster, 5-15/16" for the F-50 single stage, 7-11/16" for the G-75 booster, 8-3/16" for the G-75 single stage, 7-11/16" for the G-100 booster, and 8-3/16" for the G-100 single stage.

The table below will list the tools required for each engine, and the numbers in the table refer to the actual drawing numbers in the pages that follow.

MOTOR	F-50 BOOSTER	F-50 SINGLE	G-75 BOOSTER	G-75 SINGLE	G-100 BOOSTER	G-100 SINGLE
CASING RETAINER	02-84-035	02-84-036	02-84-037	02-84-038	02-84-039	02-84-040
RAMROD	02-84-041	02-84-041	02-84-042	02-84-042	02-84-043	02-84-043
NOZZLE TRIMMER	02-84-044	02-84-044	02-84-044	02-84-044	02-84-045	02-84-045
TAMPS	02-84-046 02-84-047	02-84-046 02-84-047	02-84-046 02-84-047	02-84-046 02-84-047	02-84-048 02-84-049	02-84-048 02-84-049
NOZZLE FORMER	02-84-050	02-84-050	02-84-051	02-84-051	02-84-052	02-84-052
CORING PINTLE	02-84-053	02-84-053	02-84-054	02-84-054	02-84-054	02-84-054
BULKHEAD PINTLE	02-84-032	02-84-032	02-84-032	02-84-032	02-84-032	02-84-032
PINTLE SLEEVE	02-84-055	02-84-055	02-84-055	02-84-055	02-84-056	02-84-056
BULKHEAD TAMP	02-84-057	02-84-057	02-84-057	02-84-057	02-84-058	02-84-058


F-50
40 lbs.
20 lbs.
1 SEC.

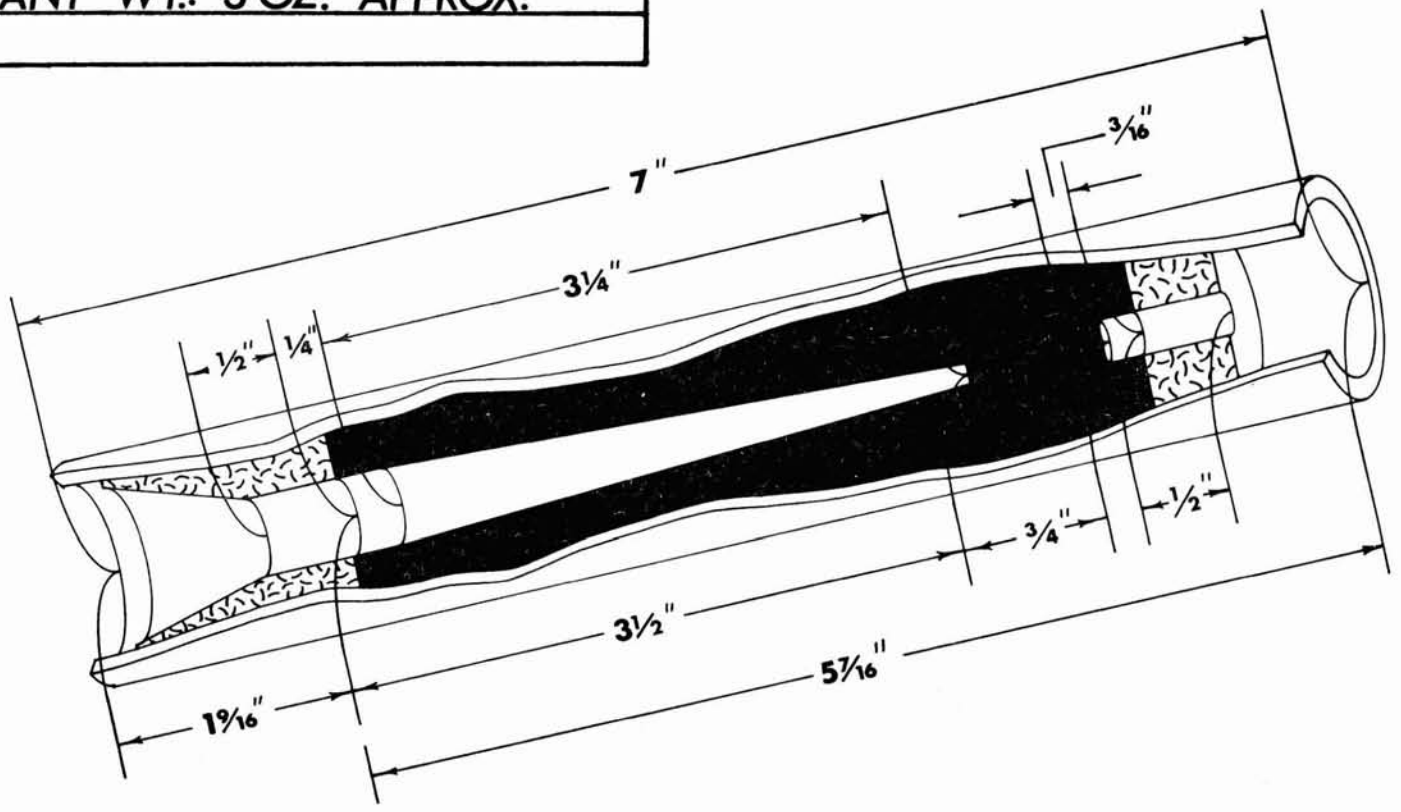

G-75
60 lbs.
40 lbs.
20 lbs.
1 SEC.


G-100
80 lbs.
40 lbs.
1 SEC.

TELEFLITE CORPORATION

FUNCTION: **F-50 BOOSTER**

PROPELLANT WT.: 3 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 INCH	TOTAL IMPULSE: 53 NT.-SECS.
NOZZLE DIA.: 7/16 INCH	PEAK THRUST: 36 LBS.
CORE LENGTH: 3 1/2 INCHES	AVERAGE THRUST: 11 LBS.

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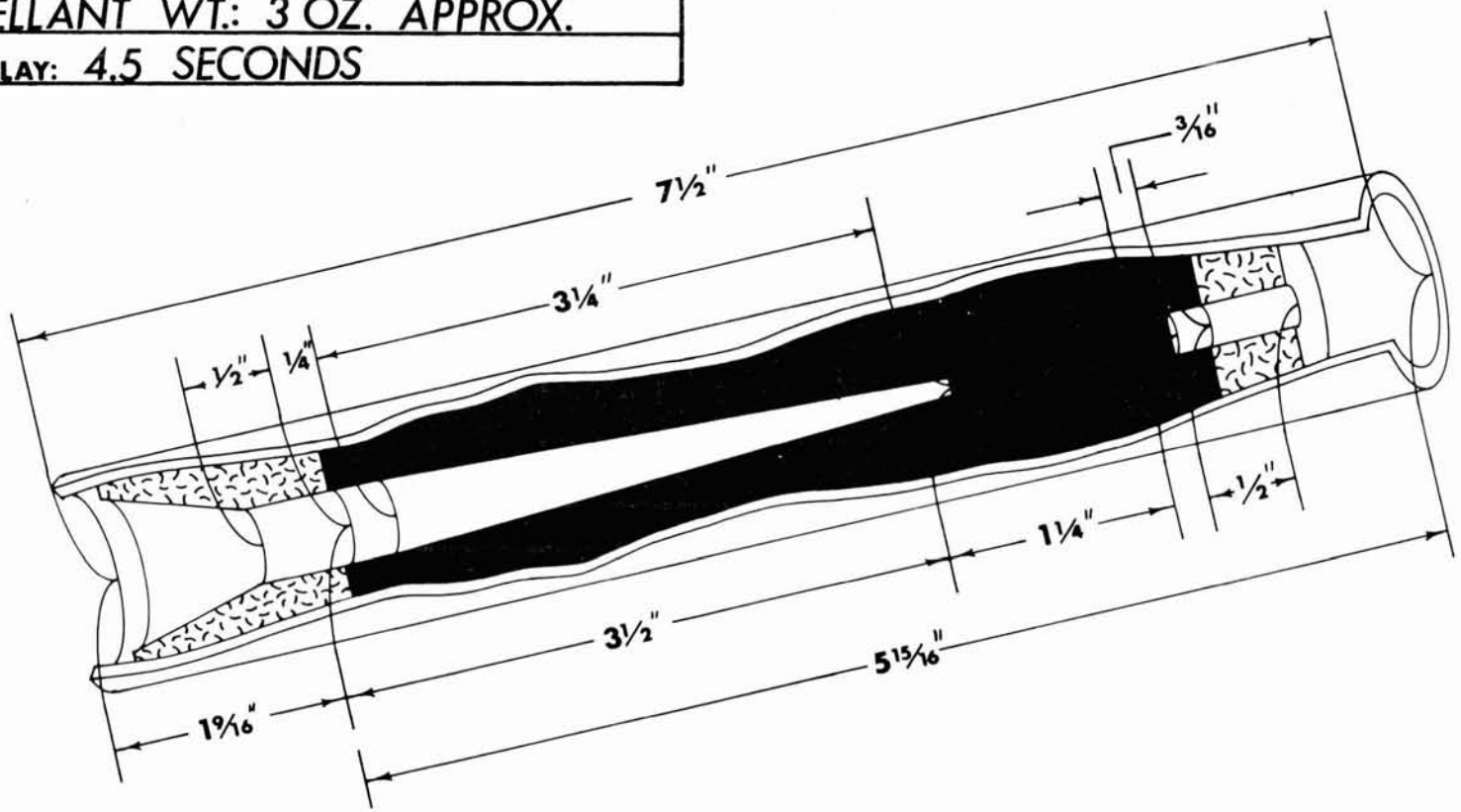
TELEFLITE CORPORATION

FUNCTION: **F-50 SINGLE STAGE**

PROPELLANT WT.: 3 OZ. APPROX.

TIME DELAY: 4.5 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 INCH	TOTAL IMPULSE: 53 NT.-SECS.
NOZZLE DIA.: 7/16 INCH	PEAK THRUST: 36 LBS.
CORE LENGTH: 3 1/2 INCHES	AVERAGE THRUST: 11 LBS.

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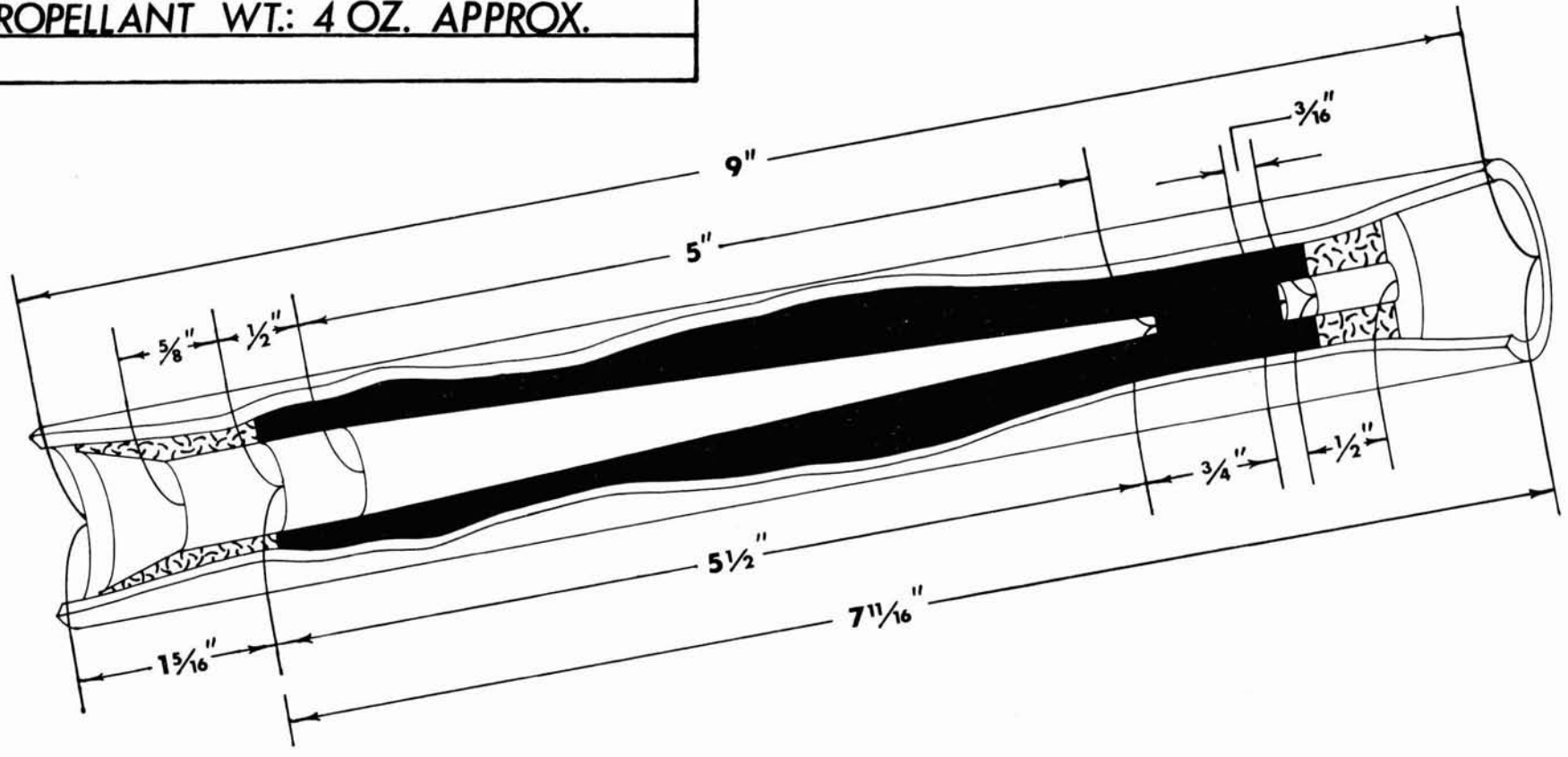
TELEFLITE CORPORATION

FUNCTION: **G-75 BOOSTER**

PROPELLANT WT.: 4 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 INCH	TOTAL IMPULSE: 80 NT.-SECS.
NOZZLE DIA.: 9/16 INCH	PEAK THRUST: 45-55 LBS.
CORE LENGTH: 5 1/2 INCHES	AVERAGE THRUST: 17 LBS.

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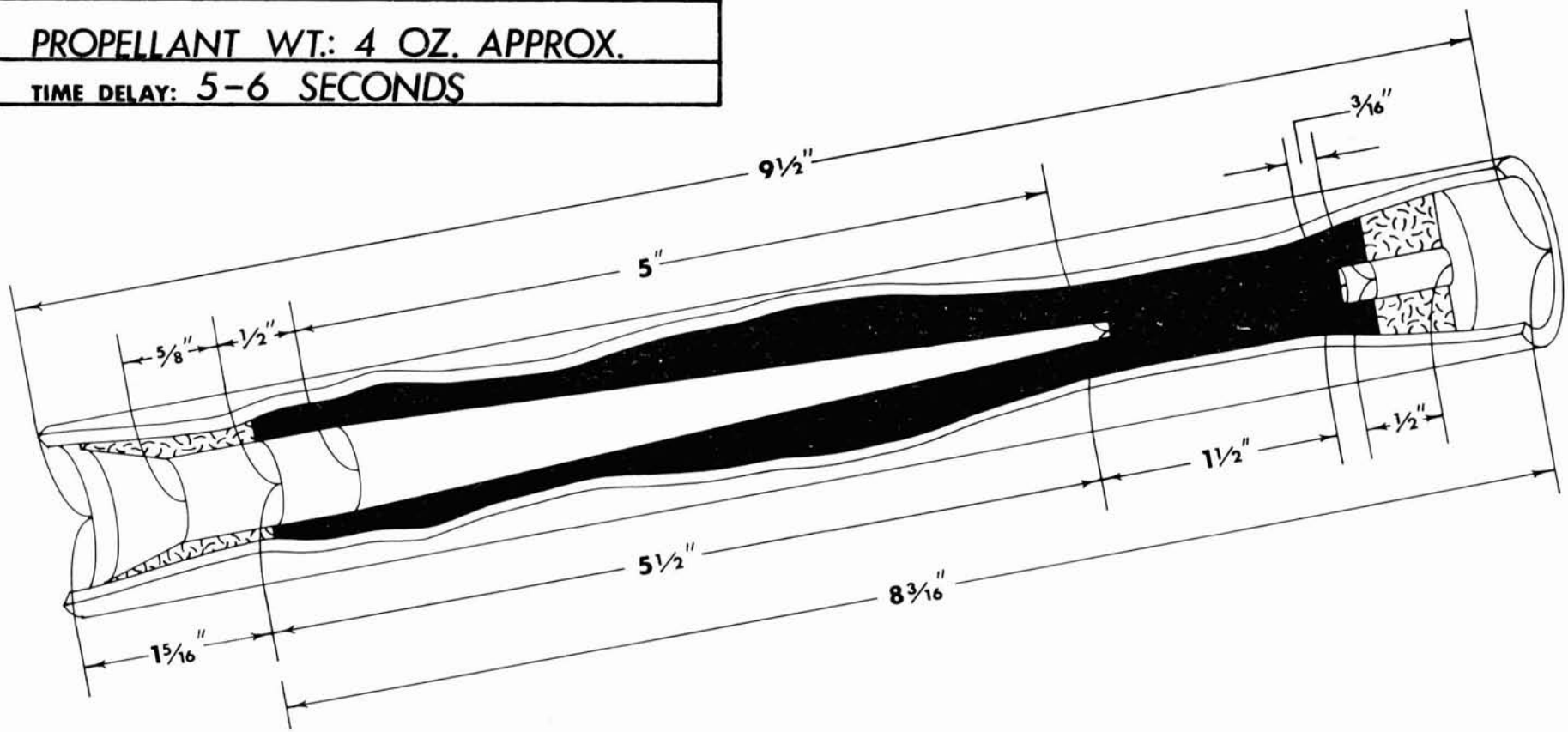
TELEFLITE CORPORATION

FUNCTION: **G-75 SINGLE STAGE**

PROPELLANT WT.: 4 OZ. APPROX.

TIME DELAY: 5-6 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 INCH	TOTAL IMPULSE: 80 NT.-SECS.
NOZZLE DIA.: 9/16 INCH	PEAK THRUST: 45-55 LBS.
CORE LENGTH: 5 1/2 INCHES	AVERAGE THRUST: 17 LBS.

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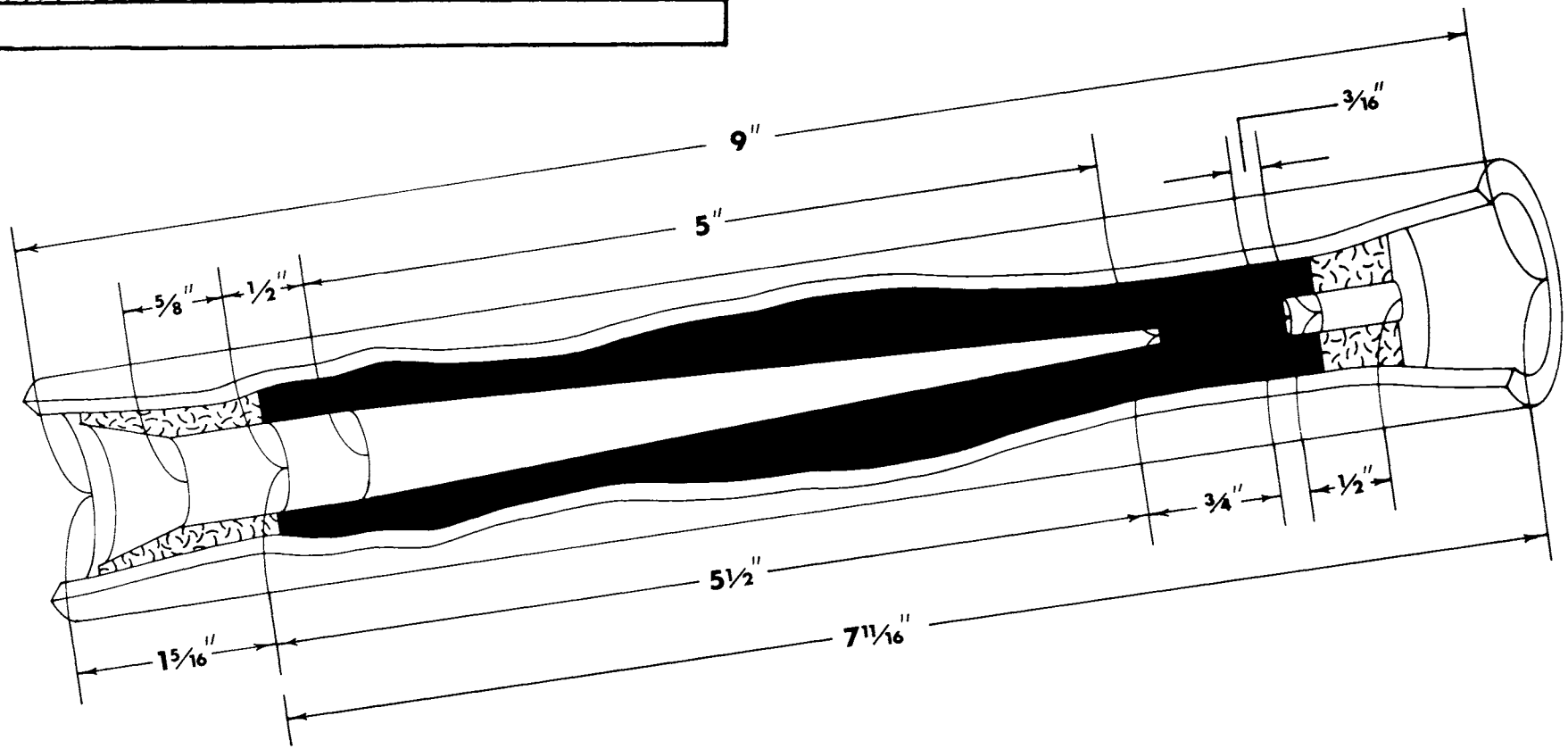
TELEFLITE CORPORATION

FUNCTION: **G-100 BOOSTER**

PROPELLANT WT.: 5 OZ. APPROX.



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 1/8 INCH	TOTAL IMPULSE: 120 NT.-SECS.
NOZZLE DIA.: 9/16 INCH	PEAK THRUST: 360 NTS. (80 LBS.)
CORE LENGTH: 5 1/2 INCHES	AVERAGE THRUST: 105 NTS. (24 LBS.)

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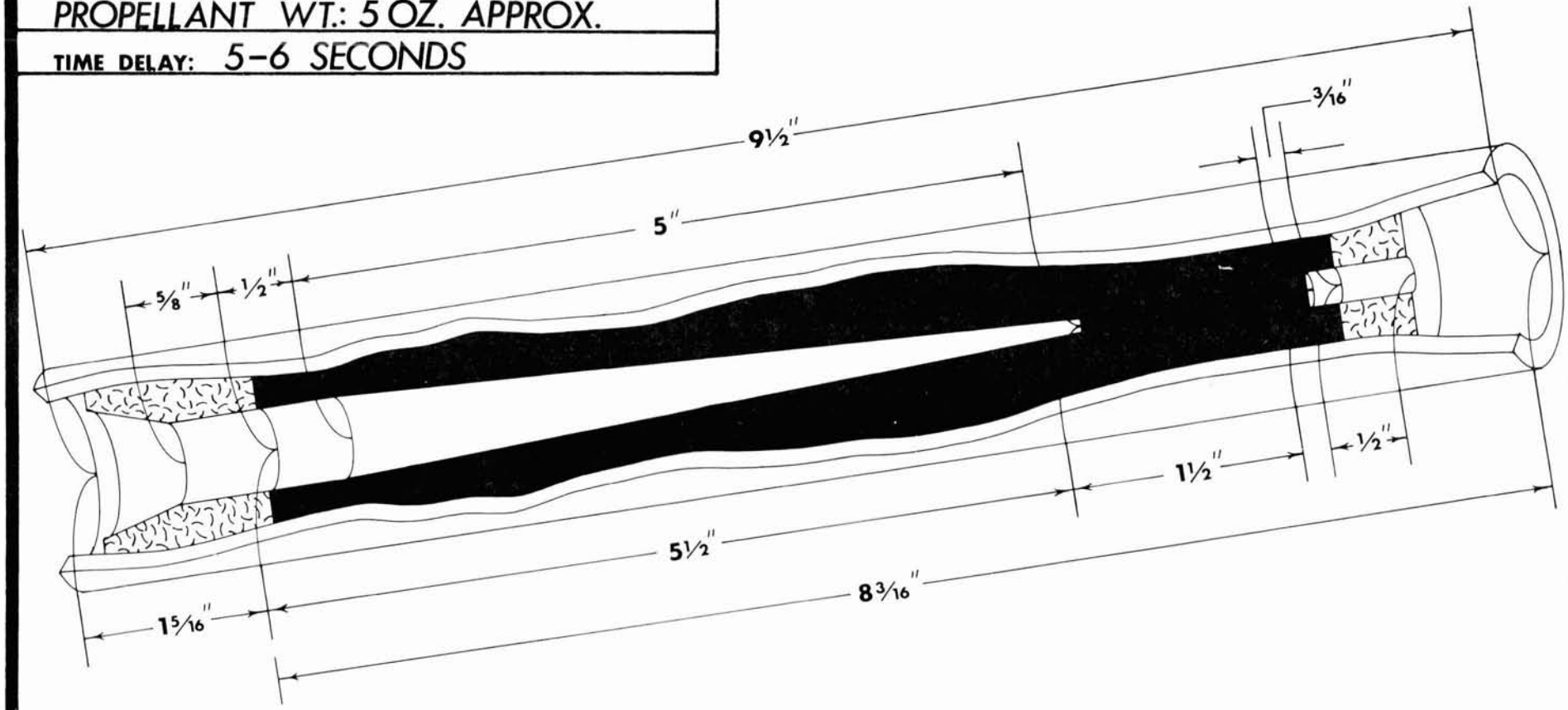
FUNCTION: **G-100 SINGLE STAGE**

PROPELLANT WT.: 5 OZ. APPROX.

TIME DELAY: 5-6 SECONDS



CRITICAL SPECS.	PERFORMANCE RATINGS
CASING I.D.: 1 1/8 INCH	TOTAL IMPULSE: 120 NT.-SECS.
NOZZLE DIA.: 9/16 INCH	PEAK THRUST: 360 NTS. (80 LBS.)
CORE LENGTH: 5 1/2 INCHES	AVERAGE THRUST: 105 NTS. (24 LBS.)

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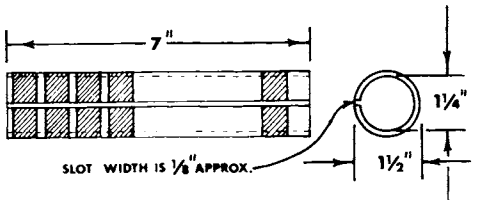
ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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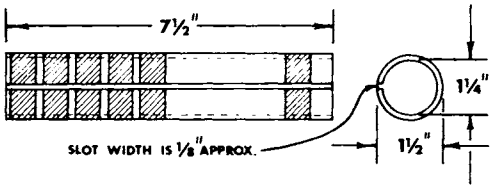
TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET
NAME: CASING RETAINER FOR F-50 BOOSTER ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-035

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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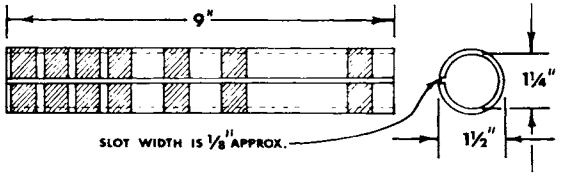
TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET
NAME: CASING RETAINER FOR F-50 SINGLE STAGE ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-036

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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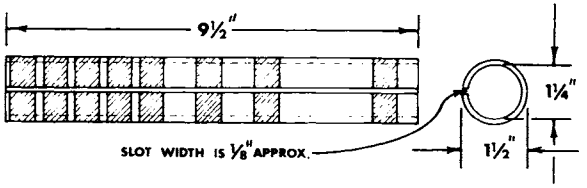
TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET
NAME: CASING RETAINER FOR G-75 BOOSTER ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-037

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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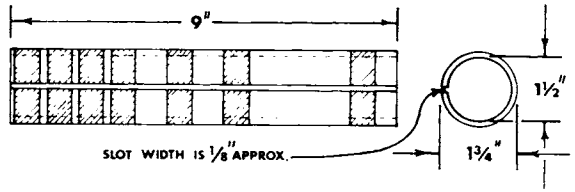
TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET
NAME: CASING RETAINER FOR G-75 SINGLE STAGE ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-038

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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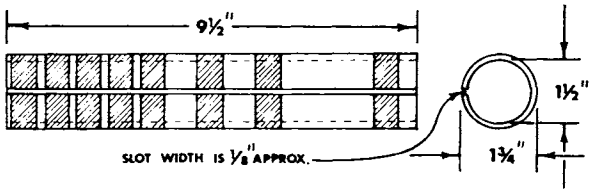
TELEFLITE CORPORATION

UNIT: G-100 TOOL SET
NAME: CASING RETAINER FOR G-100 BOOSTER ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-039

ENGINE FRONT



SHADED AREAS INDICATE
SUGGESTED CLAMP LOCATIONS

MATERIAL: **SCHEDULE 40 P.V.C.**

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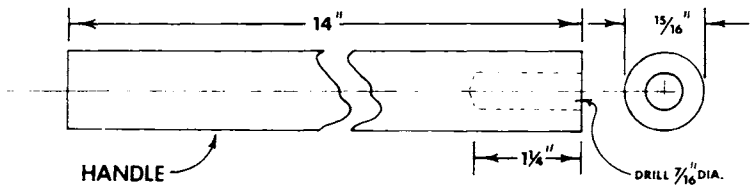
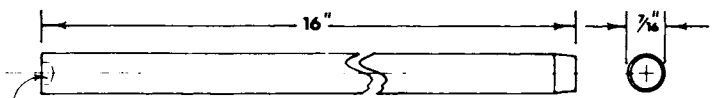
TELEFLITE CORPORATION

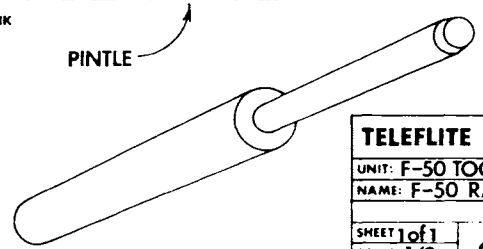
UNIT: G-100 TOOL SET
NAME: CASING RETAINER FOR G-100 STAGE ENGINE
SHEET 1 of 1
SCALE: 1/4

02-84-040





IN THE F-50 RAMROD THE PINTLE AND THE HANDLE REMAIN UNATTATCHED.



MATERIAL: **STEEL**

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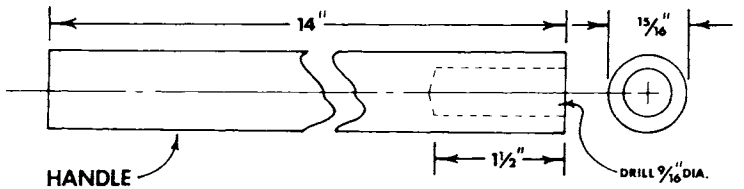
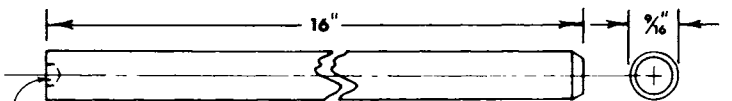
TELEFLITE CORPORATION

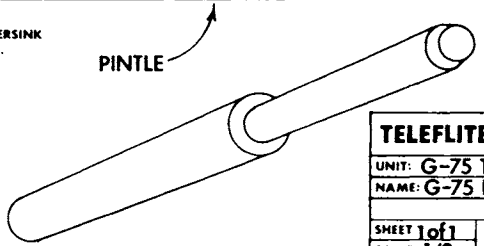
UNIT: F-50 TOOL SET
NAME: F-50 RAMROD
SHEET 1 of 1
SCALE: 1/2

02-84-041





IN THE G-75 RAMROD THE PINTLE AND THE HANDLE REMAIN UNATTATCHED.



MATERIAL: **STEEL**

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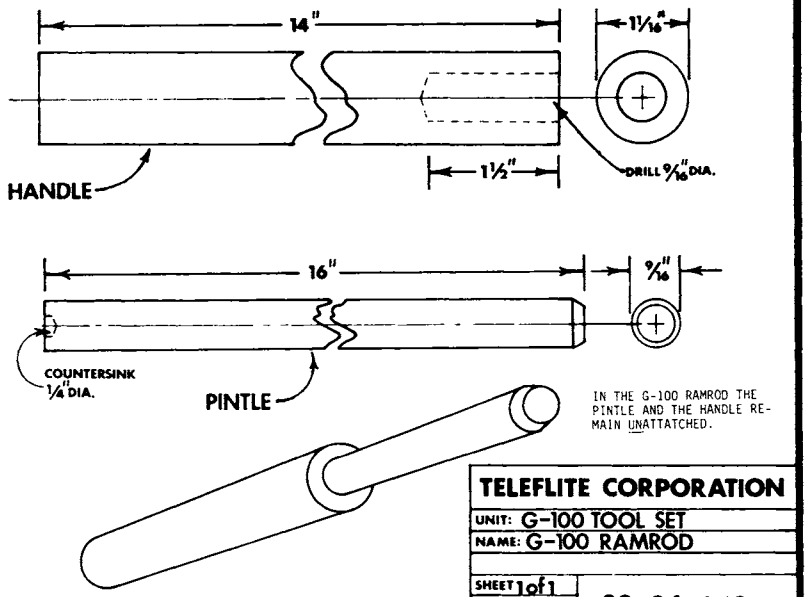
TELEFLITE CORPORATION

UNIT: G-75 TOOL SET
NAME: G-75 RAMROD
SHEET 1 of 1
SCALE: 1/2

02-84-042



TELEFLITE CORPORATION

UNIT: G-100 TOOL SET	
NAME: G-100 RAMROD	
SHEET 1 of 1	02-84-043
SCALE: 1/2	

MATERIAL: STEEL

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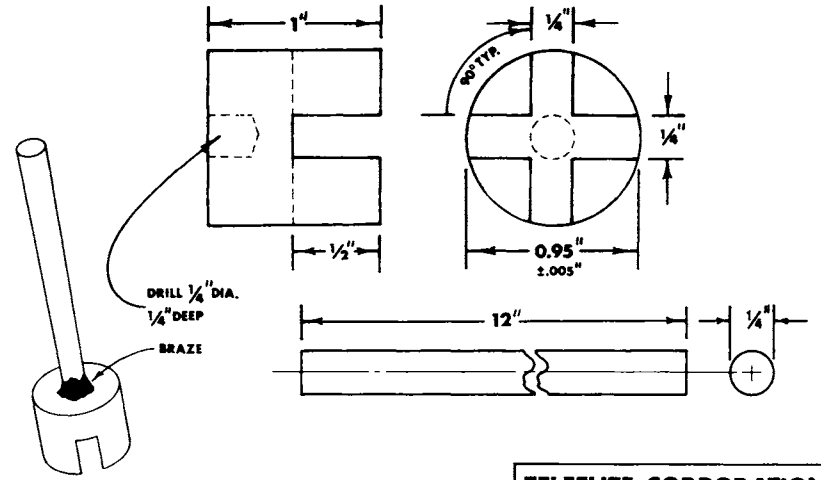

THE SHAFT OF THE NOZZLE TRIMMER SHOULD BE INSERTED INTO THE HOLE DRILLED INTO THE TRIMMER HEAD AND BRAZED INTO PLACE.

TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET	
NAME: 1 INCH CASING NOZZLE TRIMMER	
SHEET 1 of 1	02-84-044
SCALE: 1:1	

MATERIAL: STEEL

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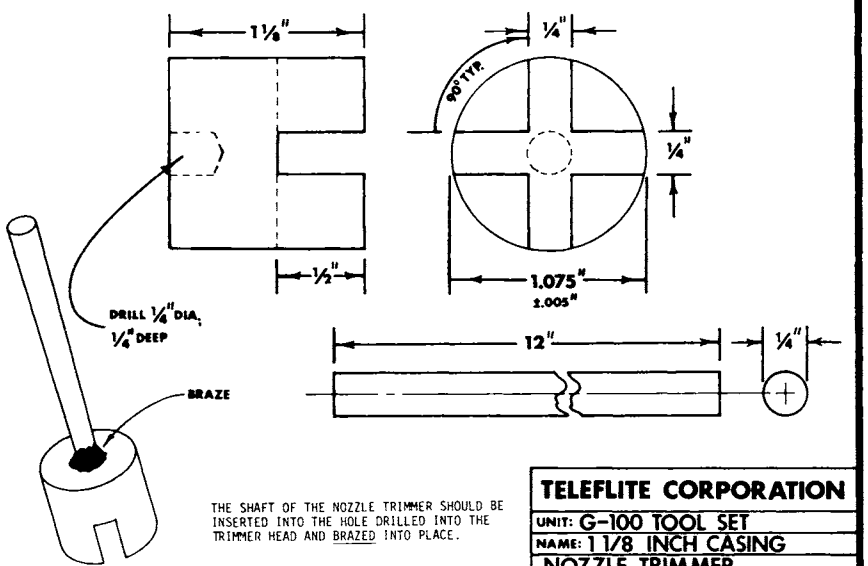

THE SHAFT OF THE NOZZLE TRIMMER SHOULD BE INSERTED INTO THE HOLE DRILLED INTO THE TRIMMER HEAD AND BRAZED INTO PLACE.

TELEFLITE CORPORATION

UNIT: G-100 TOOL SET	
NAME: 1 1/8 INCH CASING NOZZLE TRIMMER	
SHEET 1 of 1	02-84-045
SCALE: 1:1	

MATERIAL: STEEL

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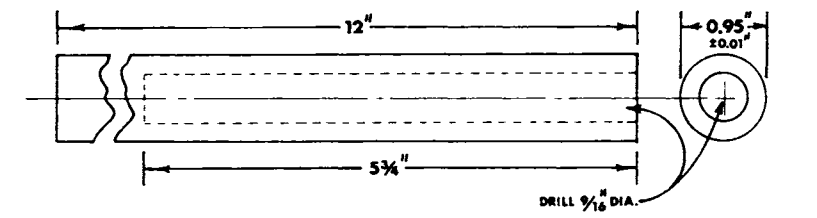

TELEFLITE CORPORATION

UNIT: F-50 thru G-75 TOOL SET	
NAME: 9/16" X 1" CORED AND FLAT TAMP	
SHEET 1 of 1	02-84-046
SCALE: 1/2	

MATERIAL: NYLON

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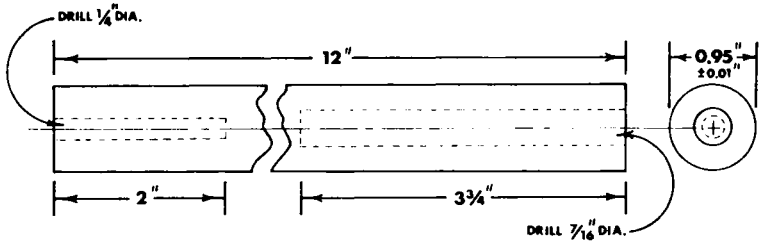

TELEFLITE CORPORATION	
UNIT: F-50 thru G-75 TOOL SET	
NAME: 7/16" X 1/4" X 1" CORED TAMP	
SHEET 1 of 1	02-84-047
SCALE: 1/2	

MATERIAL: NYLON

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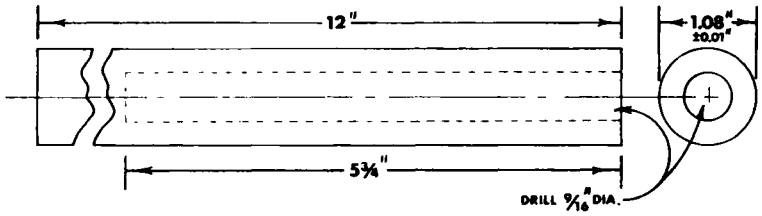

TELEFLITE CORPORATION	
UNIT: G-100 TOOL SET	
NAME: 9/16" X 1 1/8" CORED AND FLAT TAMP	
SHEET 1 of 1	02-84-048
SCALE: 1/2	

MATERIAL: NYLON

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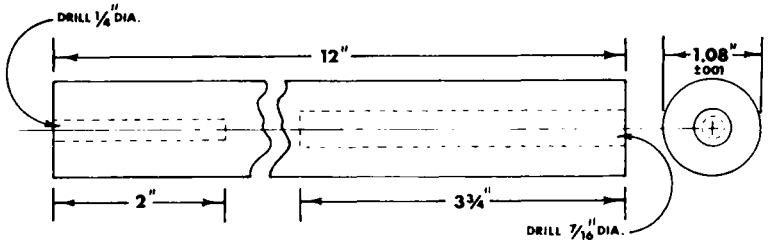

TELEFLITE CORPORATION	
UNIT: G-100 TOOL SET	
NAME: 7/16" X 1/4" X 1 1/8" CORED TAMP	
SHEET 1 of 1	02-84-049
SCALE: 1/2	

MATERIAL: NYLON

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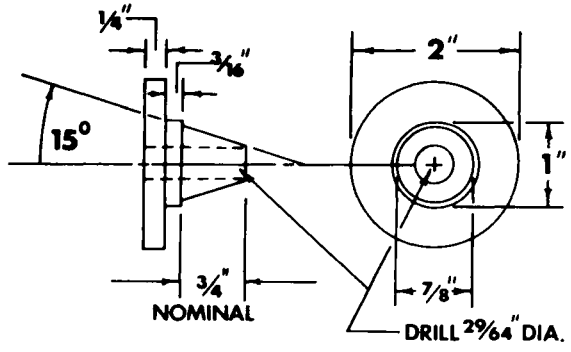

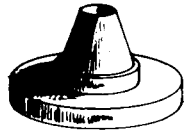

TELEFLITE CORPORATION	
UNIT: F-50 TOOL SET	
NAME: F-50 NOZZLE FORMER	
SHEET 1 of 1	02-84-050
SCALE: 1:2	

MATERIAL: STEEL

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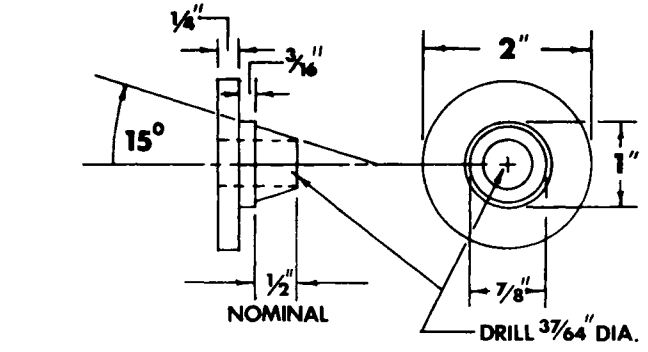

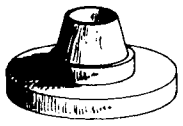

TELEFLITE CORPORATION	
UNIT: G-75 TOOL SET	
NAME: G-75 NOZZLE FORMER	
SHEET 1 of 1	02-84-051
SCALE: 1:2	

MATERIAL: STEEL

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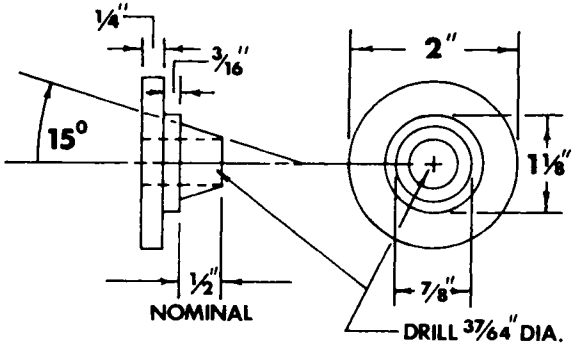

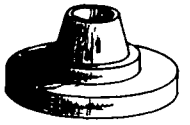

TELEFLITE CORPORATION	
UNIT: SUPER G-100 TOOL SET	
NAME: G-100 NOZZLE FORMER	
SHEET 1 of 1	02-84-052
SCALE: 1:2	

MATERIAL: STEEL

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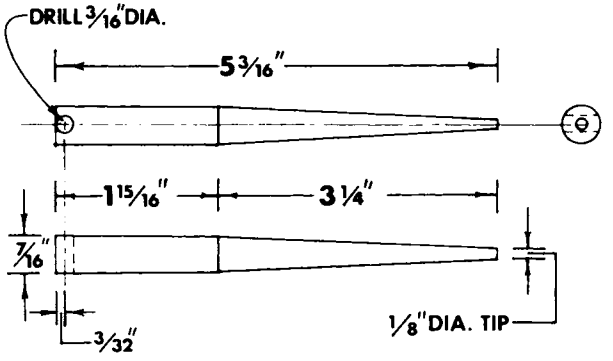

TELEFLITE CORPORATION	
UNIT: F-50 TOOL SET	
NAME: F-50 CORING PINTLE	
SHEET 1 of 1	02-84-053
SCALE: 1:2	

MATERIAL: BRASS

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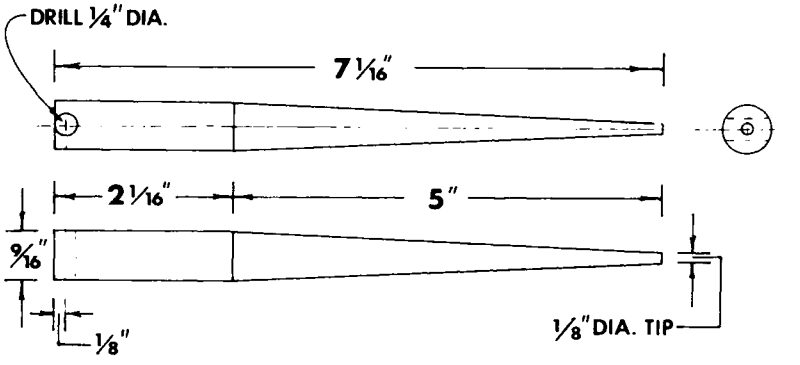

TELEFLITE CORPORATION	
UNIT: G-75 TOOL SET	
NAME: G-75 CORING PINTLE	
ALSO FOR SUPER G-100	
SHEET 1 of 1	02-84-054
SCALE: 1:2	

MATERIAL: BRASS

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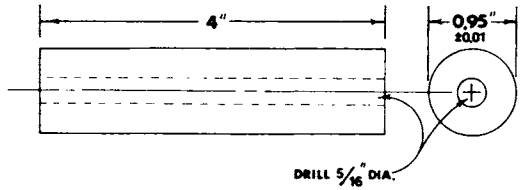

TELEFLITE CORPORATION	
UNIT: F-50 thru G-75 TOOL SET	
NAME: F-50 thru G-75 PINTLE SLEEVE	
SHEET 1 of 1	02-84-055
SCALE: 1/2	

MATERIAL: NYLON

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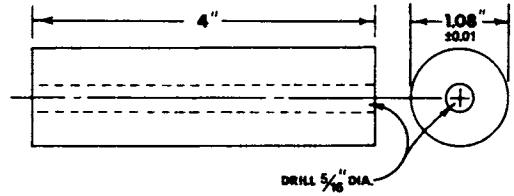

TELEFLITE CORPORATION	
UNIT: G-100 TOOL SET	
NAME: PINTLE SLEEVE (G-100)	
SHEET 1 of 1	02-84-056
SCALE: 1/2	

MATERIAL: NYLON

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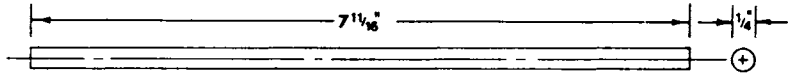

TELEFLITE CORPORATION	
UNIT: D-18 thru G-100 TOOL SET	
NAME: FORWARD BULKHEAD PINTLE	
SHEET 1 of 1	02-84-032
SCALE: 1/2	

MATERIAL: BRASS

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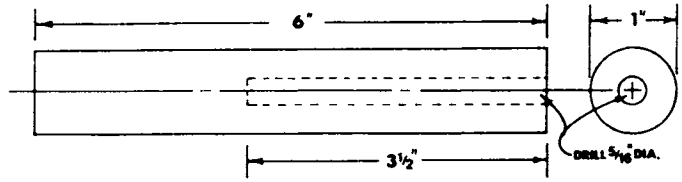

TELEFLITE CORPORATION	
UNIT: F-50 thru G-75 TOOL SET	
NAME: F-50 thru G-75 BULKHEAD TAMP	
SHEET 1 of 1	02-84-057
SCALE: 1/2	

MATERIAL: NYLON

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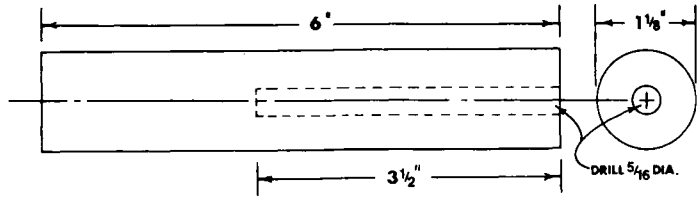

TELEFLITE CORPORATION	
UNIT: G-100 TOOL SET	
NAME: G-100 BULKHEAD TAMP	
SHEET 1 of 1	02-84-058
SCALE: 1/2	

MATERIAL: NYLON

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NOTES